

International Conference “Moon Base: a Challenge for Humanity”

Third workshop “The precursor Age”

Moscow, November 16-17, 2006

First generation particle detectors on the Moon  
for a lunar cosmic rays observatory  
*and climate change monitor*

K.P. Heiss, High Frontier Inc., USA  
C. Lobascio, Alcatel Alenia Space Italia  
P. Spillantini, Univ. and INFN, Firenze (Italy)

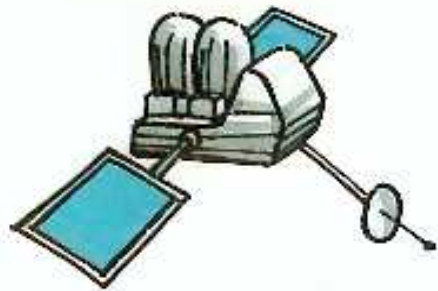
## *Preamble*

In most of the satellite borne CR experiments, as in general in all satellite borne experiments, **the mass and cost of the spacecraft and of its services (altitude and attitude control, power generation and distribution, telemetry, etc.) largely exceed the mass and cost of the experimental device.** This fact, as well the increasing concurrence by other field of the science and applications, greatly reduced in last two decades the number of flown satellite born cosmic ray experiments.

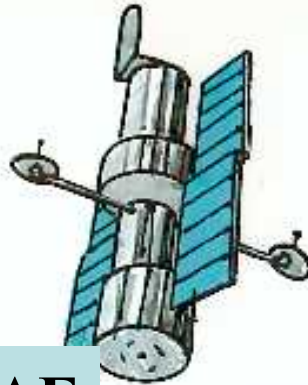
As matter of fact the possibility of installing CR experiments on an already **organized and serviced lunar habitat** can significantly reduce the required investment, as already proven for the many experiments performed on board of the MIR Space Station and of the ISS. This **compensates for the cost of the Earth-Moon transportation**, that in addition it is anticipated to decrease by a sensible factor in the next decade.-----

As it was the case in the seventies for the **Great Observatories** (Hubble telescope, CGRO, AXAF, SIRF) in view of the shuttle operations, a complete program at the forefront of space science and technology should include a set of **Moon based Observatories** to explore any aspect of the Universe.-----

For expanding our knowledge to the extreme Universe at higher energies the Moon based CR observation must be part of this program. --



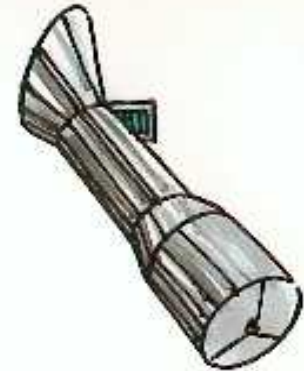
**CGRO**



**AXAF**  
(CXO)+  
(XMM)



**HST**



**SIRTF**

# THE GREAT OBSERVATORIES

FOR SPACE ASTROPHYSICS

+

**Advanced  
Composition  
Explorer  
(ACE)**

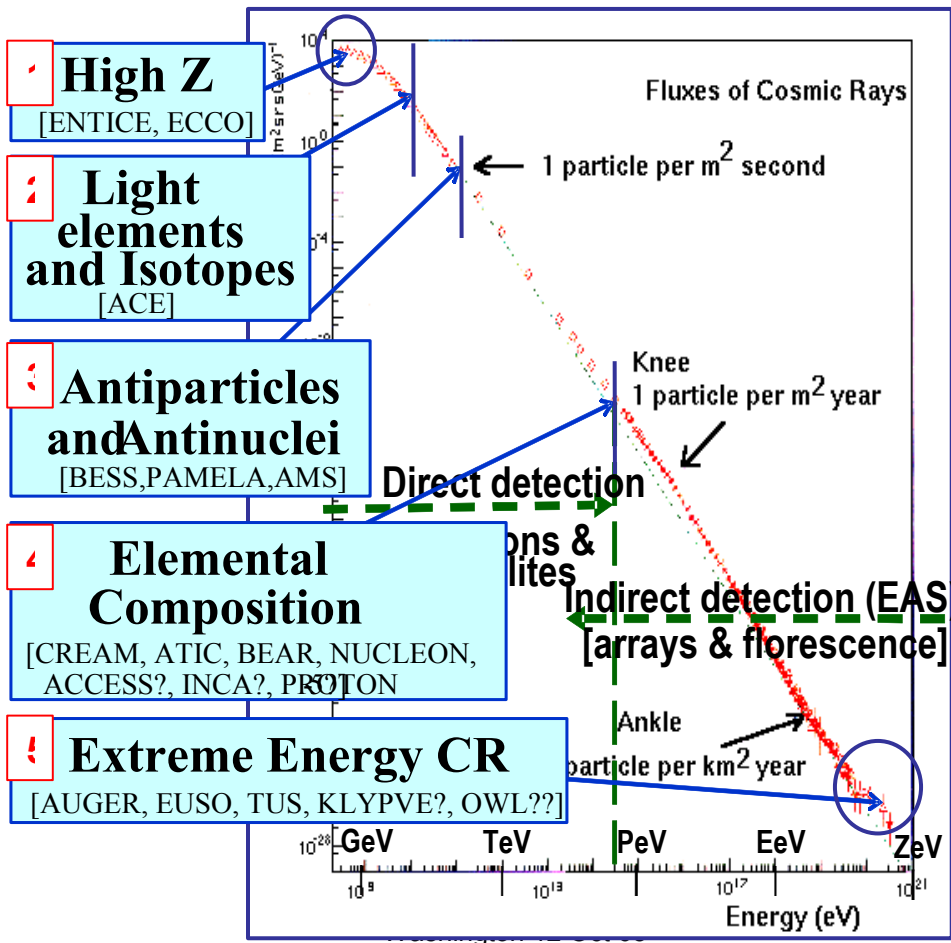
**+ Particle-Antiparticle  
Superconducting Magnet  
Facility  
(ASTROMAG)**

+

**Very Long Base  
Interferometer  
(VLBI)**

The location on the Moon offers several additional advantages, which are particularly attractive for CR physics. The most relevant are:

- **absence of a magnetic field**: all the CR to reach the Moon surface;
- **absence of an atmosphere**: all CR reaching the Moon surface are primary;
- **low gravity**: advantage for supporting structure, but disadvantage for maintaining precise shapes of light large instruments (e.g. for inflatable optical elements).



Washington, Oct. 2005  
(last slide)

- High Z:** ! HNeXplorer (HNX) [exp. ENTICE + ECCO] in 'stand by' possible only on the Moon surface
- Isotopes ( $E > \text{GeV}/n$ ):** ! on Earth orbit  $\approx 80$  are accessible but no plans exist light isotopes from BESS, PAMELA, AMS in next years high rate assured on the Moon up to very high E
- Rare components:** ! antiN/N up to  $< 10^{-9}$  (AMS)  
antip, e+ up to a  $> 200$  GeV (PAMELA ed AMS)  
electrons up to  $> 3$  TeV (PAMELA, AMS, CALET)  
1-10 TeV region on reach on the Moon surface

Washington, Oct. 2005  
(first slide)

- Elemental composition:** ! up to 100 TeV by ballooning (going on)  
up to 1 PeV in orbit (several projects and concepts)  
up to 100 PeV (well behind the knee) on the Moon
- Ultra High Energies:** ! up to few \* 100 EeV on Earth surface (going on)  
up to 1000 EeV from orbit (but EUSO in 'stand by')  
up to a few 10 ZeV from the Moon surface,  
a UHE Neutrino Observatory ( $E_{\nu} > 10^{19}$ ) is feasible

**What detectors for the first CR experiments on the Moon?**

## Zero generation experiments:

Install on the Moon the experiments planned for satellites or ISS, and that are long time in stand by because too massive and difficult to be operated In LEO:

Examples:

- - ECCO for very high Z (supernovae rate counting) [small changes]
- - Rare elements, radioactive isotopes [new, ISOMAX-like magnetic spectrometer]
- - Elemental composition at knee
  - [ACCESS class, possibly larger acceptance]
  - [CHICAGO EGG spectrometer, but longer exposition]

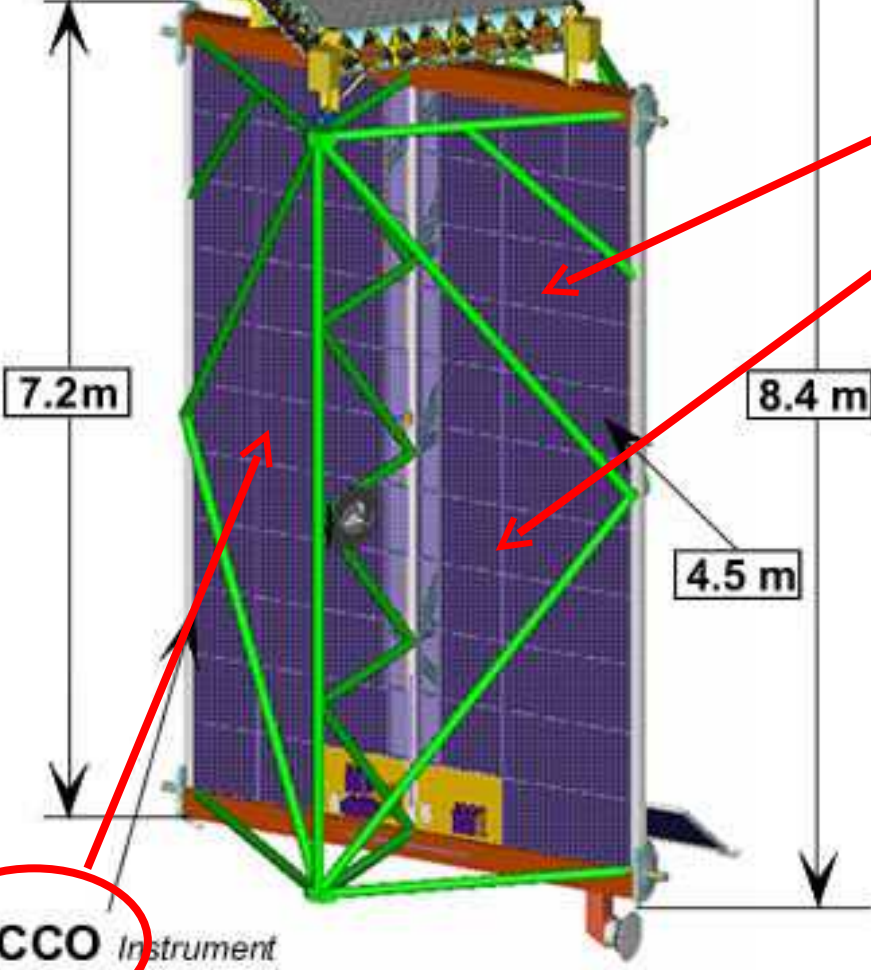
# HNX

(The Heavy Nuclei eXplorer)

ENTICE Instrument

High Z (>Fe)

Electronic device



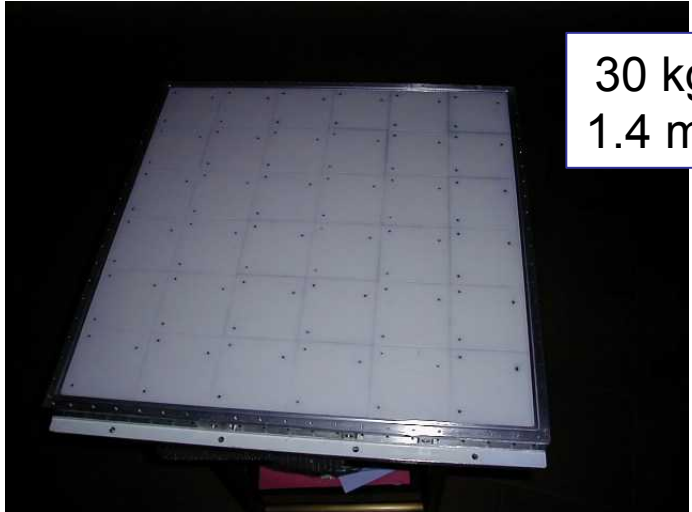
Very High Z (actinides)

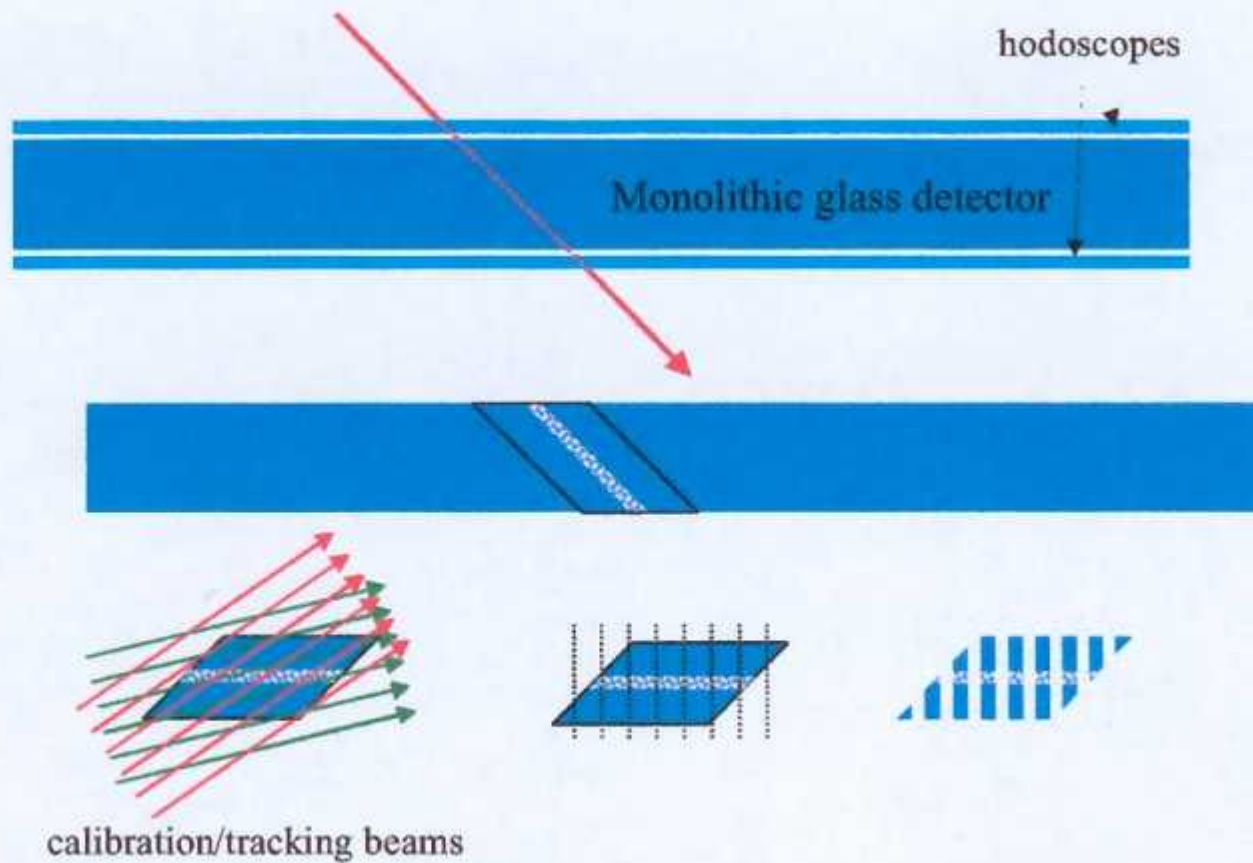
Etching of "charged" glasses

On the Moon:

- no magnetic field
- easy deployed
- easily recovered

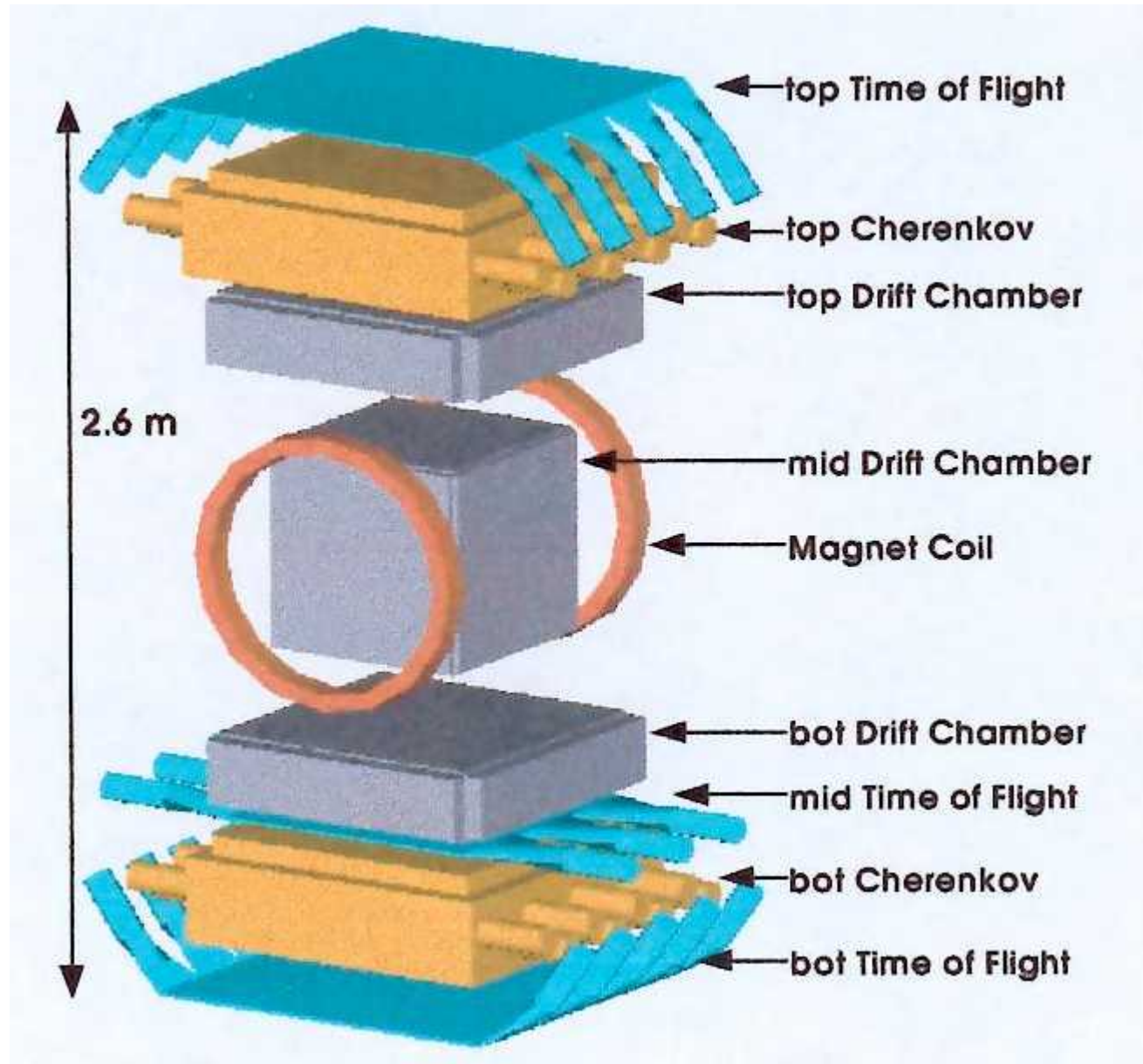
Mass << 100 kg/m<sup>2</sup>



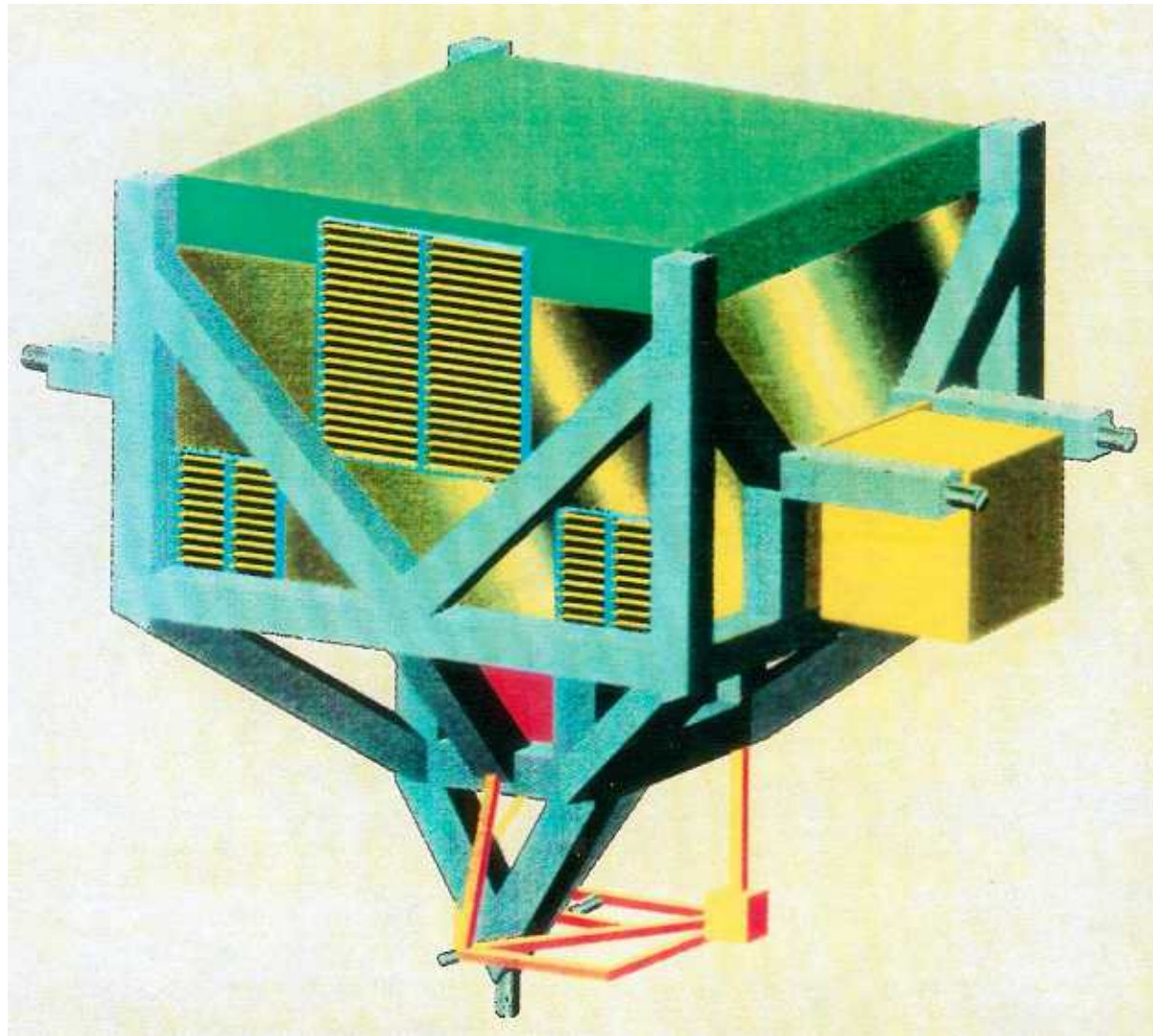


**Fig. 1.** Schematic of layout, coring, calibration and dicing of an ECCO detector.

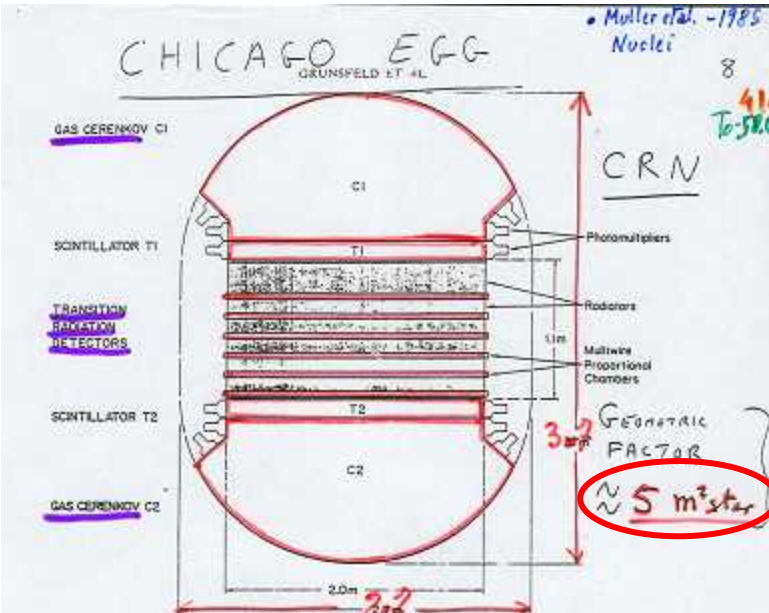
# ISOMAX



# ACCESS

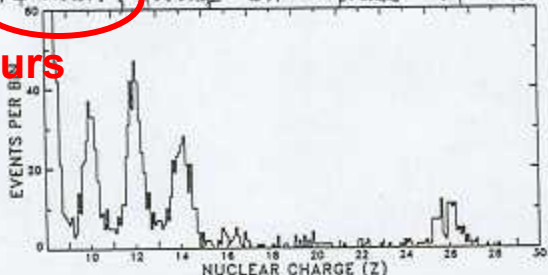


# CRN (Chicago egg), 1985



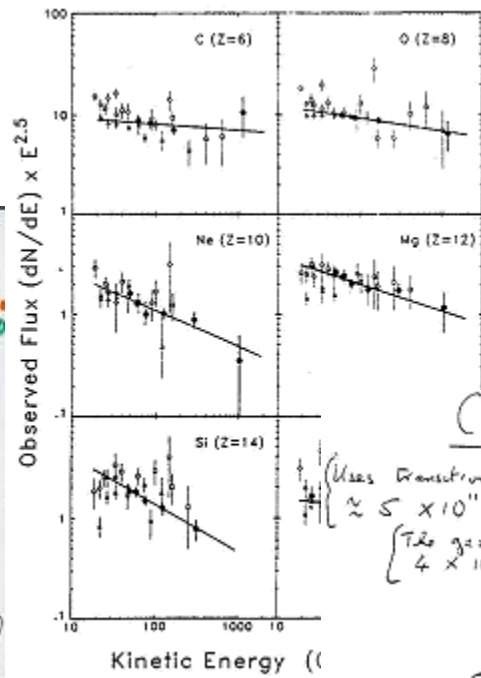
LAUNCHED 29 July 1985 (Spacelab-2)  
 Not observed in at full aperture corrected for occultation was 94 hours using an aperture of 20 m<sup>2</sup> ster days

94 hours

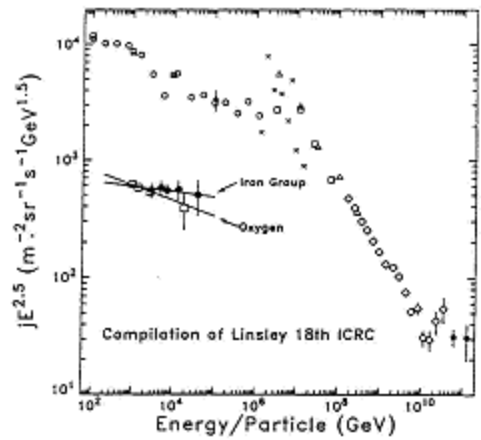


Charge histogram of cosmic ray Neon to Iron at energies greater than 50 GeV/amu. The charge information is derived using only the scintillation counters T1 and T2

Energy measurement up to  $\approx 3 \times 10^{12}$  eV/N



CHICAGO EGG

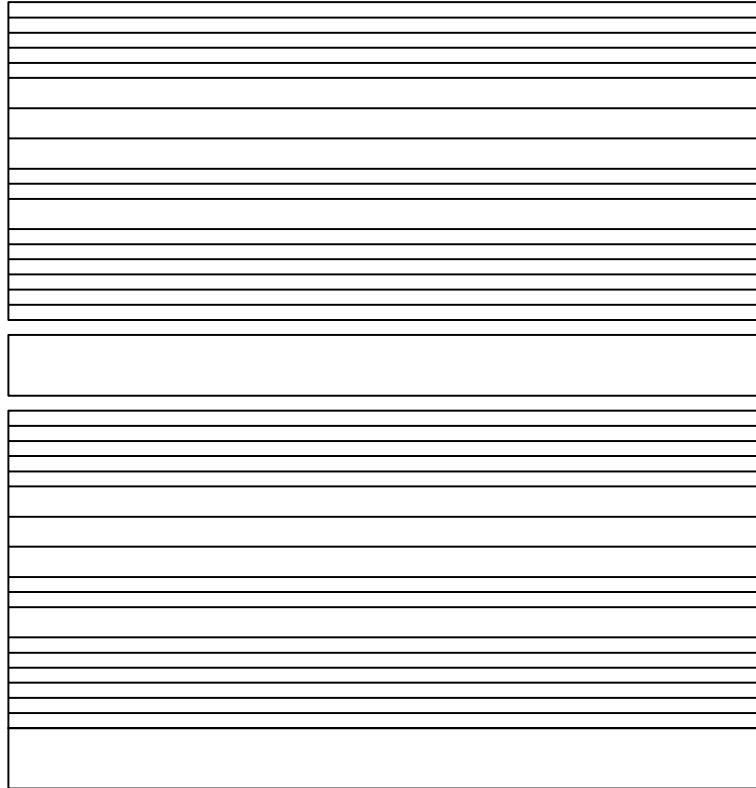


The all-particle energy spectrum as compiled by Linsley (1962) and the spectra of O and the Fe group (Z = 25, 26, 27) as measured in this experiment. The lines represent the power-law fits to the O and the Fe group data obtained in this experiment. Note that in the absence of absolute form, the normalization of our data is somewhat arbitrary.

{ Proposed (approved?) for re-flight on Mir-2.  
 { Mir-2 first launch scheduled for 1993 (but not yet approved)

←-----  $\varnothing \approx 4 \div 5 \text{ m}$  -----→

↑  
-----  
 $\approx 4 \div 6 \text{ m}$   
-----  
↓



Dimensions compatible  
with the next future  
transport systems

**TRD's + Cherenkov's Spectrometer**

## First generation experiments

### a) Technical progress on sensors

Examples:

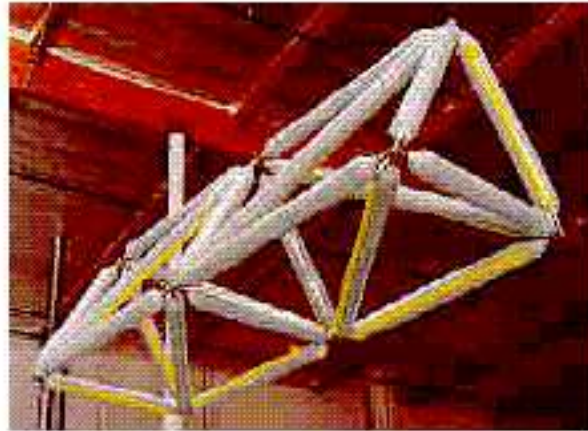
- **High efficiency solid state X-ray sensors** [currently under R&D, essential for TRD's, [cryo] Cherenkov's].
- **Large area covered SIM systems** [currently under R&D, essential to improve RICH's, trackers]

### b) Progress on detection systems

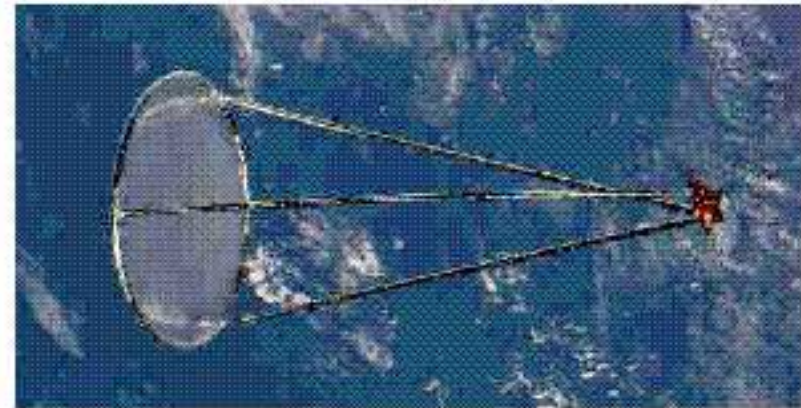
- **Inflatable detectors and other elements** (gas counters (?), trusses, stretched membranes, deployed large mirrors, gaseous optical lenses, expandable magnetic lenses,..)  
[used in several other fields, important for calorimetry, large structures, etc ]
- **Use the terrestrial magnetic field** in magnetic spectrometers (precise direction + energy measurement )  
[for antiparticles, hunting for antinuclei, but also for composition]
- **Use calorimetry at high energy** (passive material on the moon, sensor from Earth)



## Space Inflatable Applications

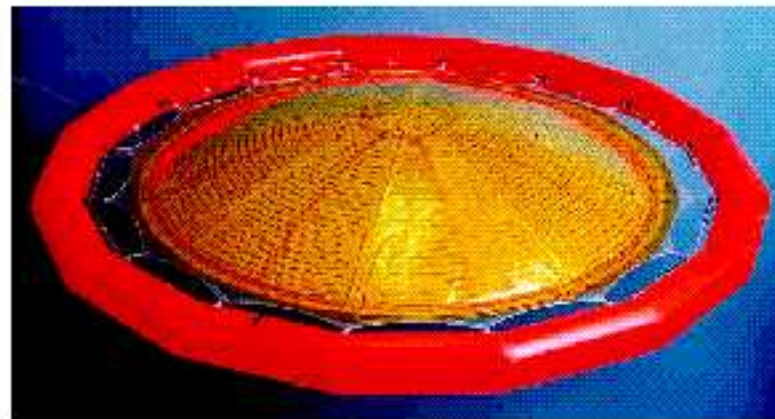


Trusses



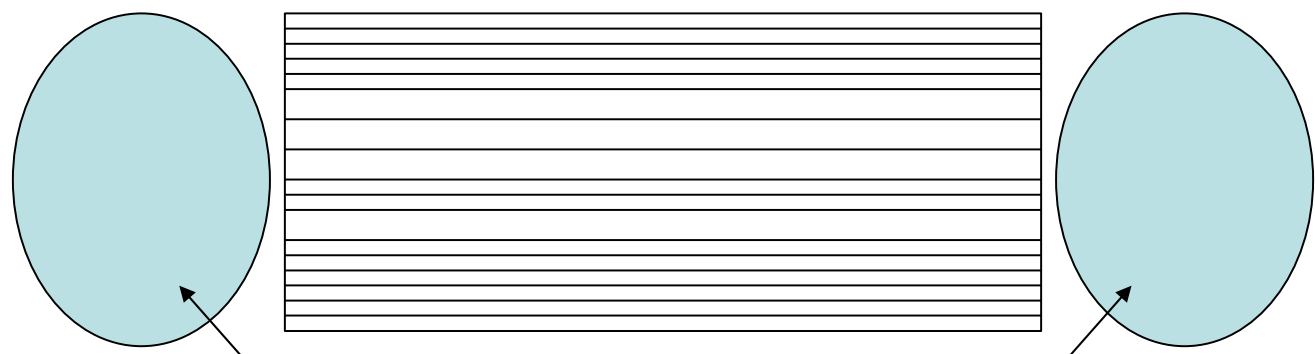
Space Antenna

**ULDB  
Project**



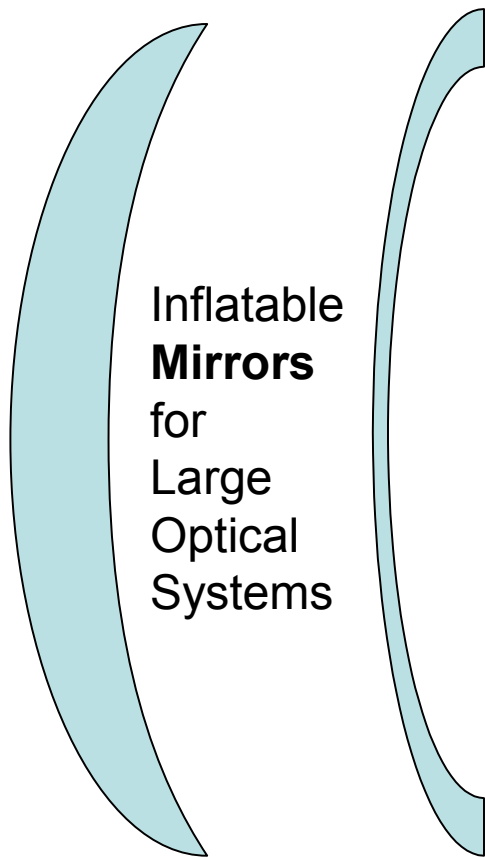
Rigidizable Antenna

← fits the transport system →

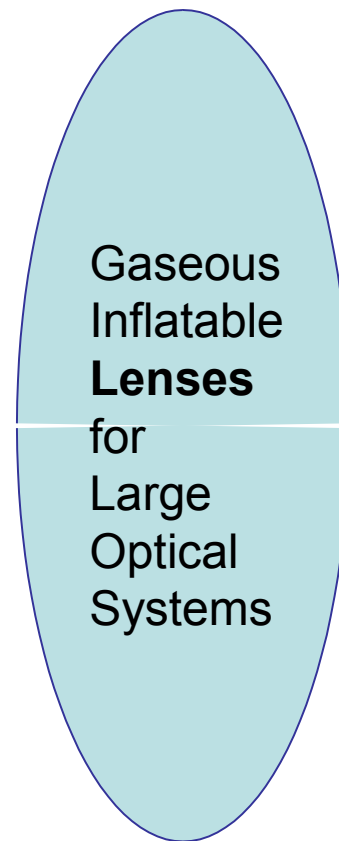


TRD's system

TRD's inflatable doughnut

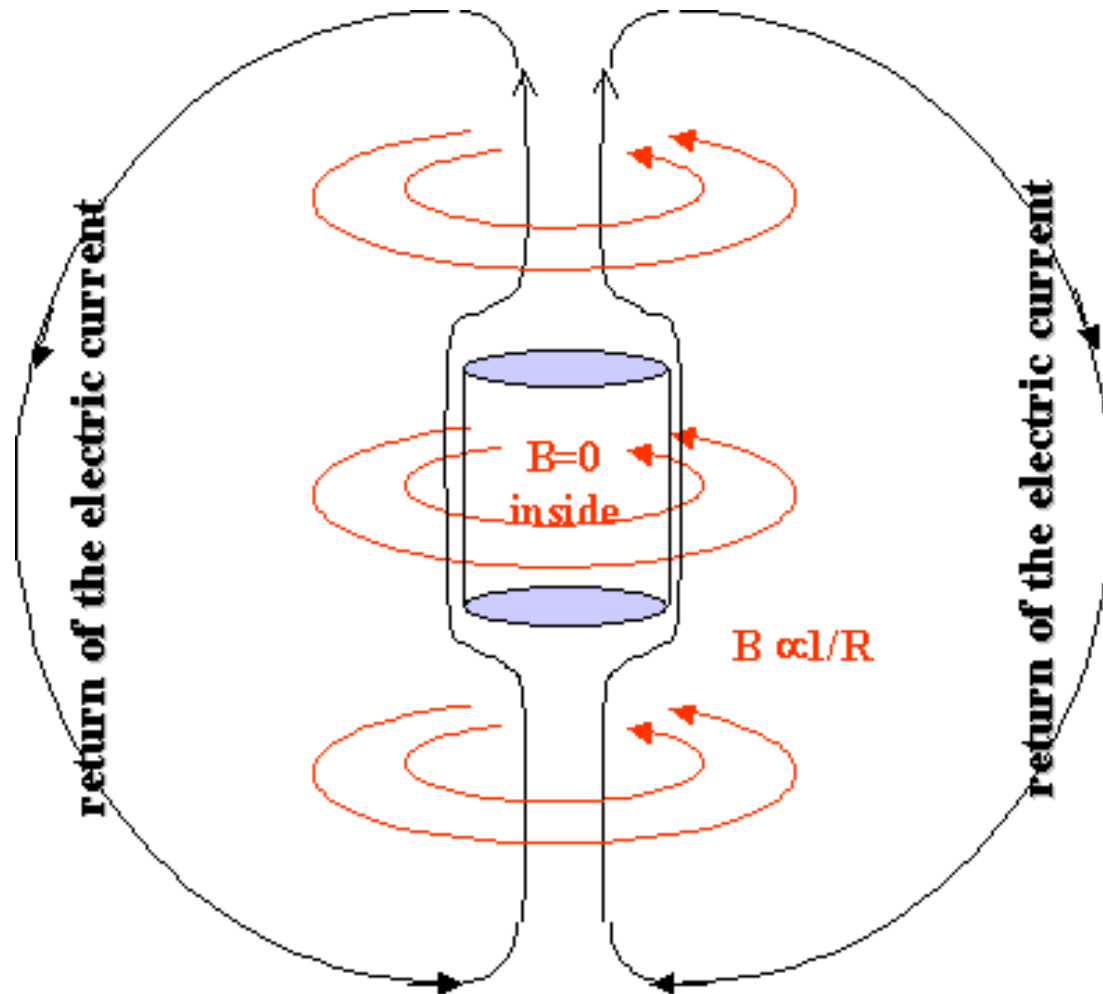


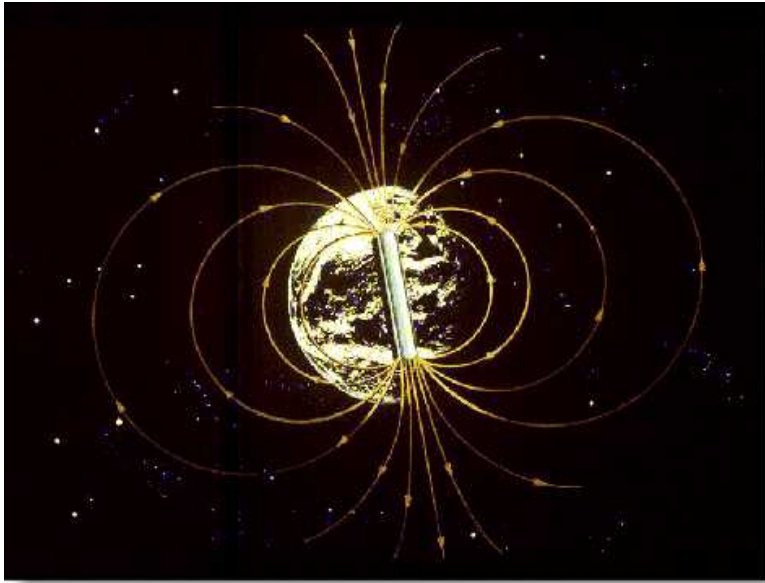
Inflatable  
**Mirrors**  
for  
Large  
Optical  
Systems



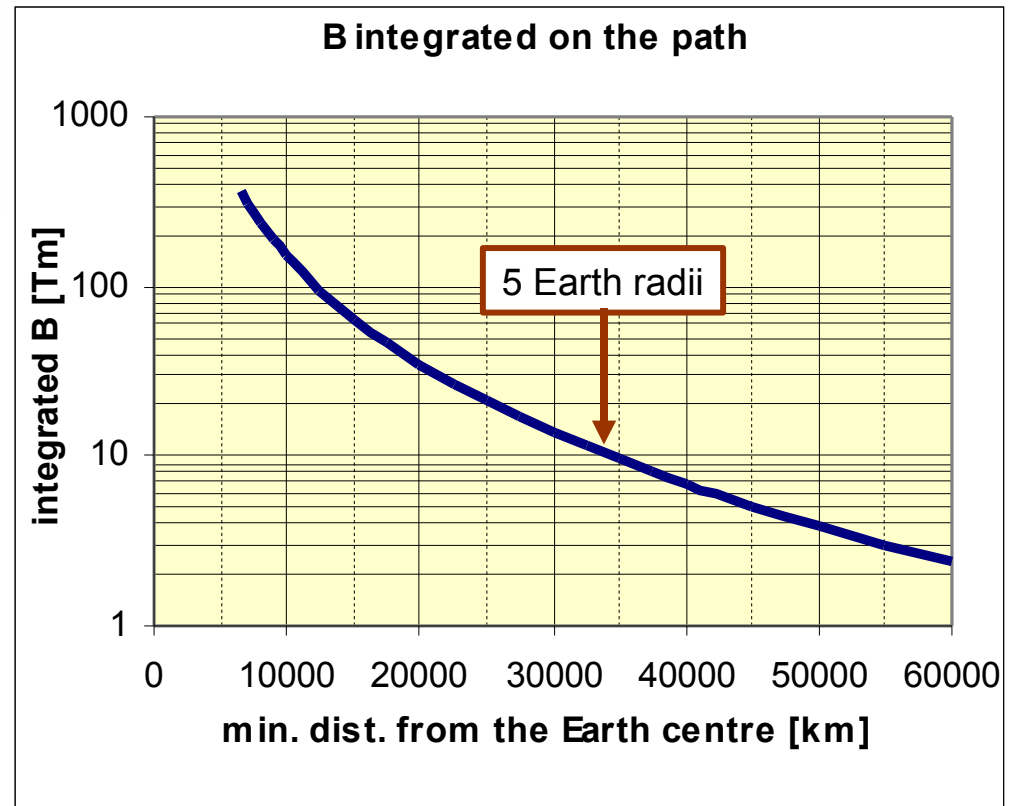
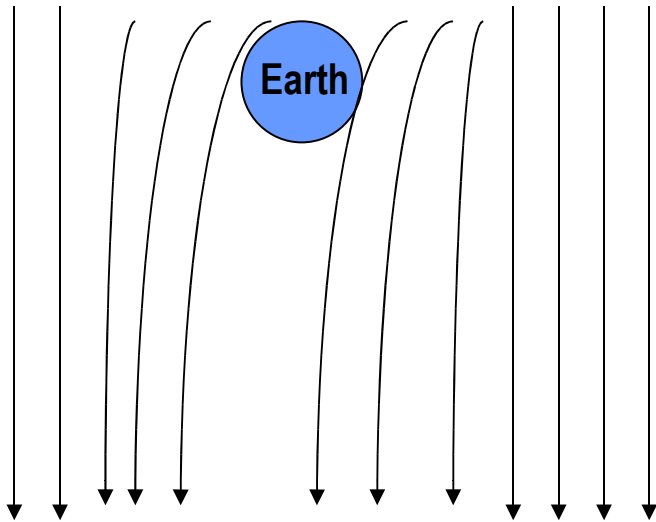
Gaseous  
Inflatable  
**Lenses**  
for  
Large  
Optical  
Systems

Deployable external conductor for returning the current of the toroid



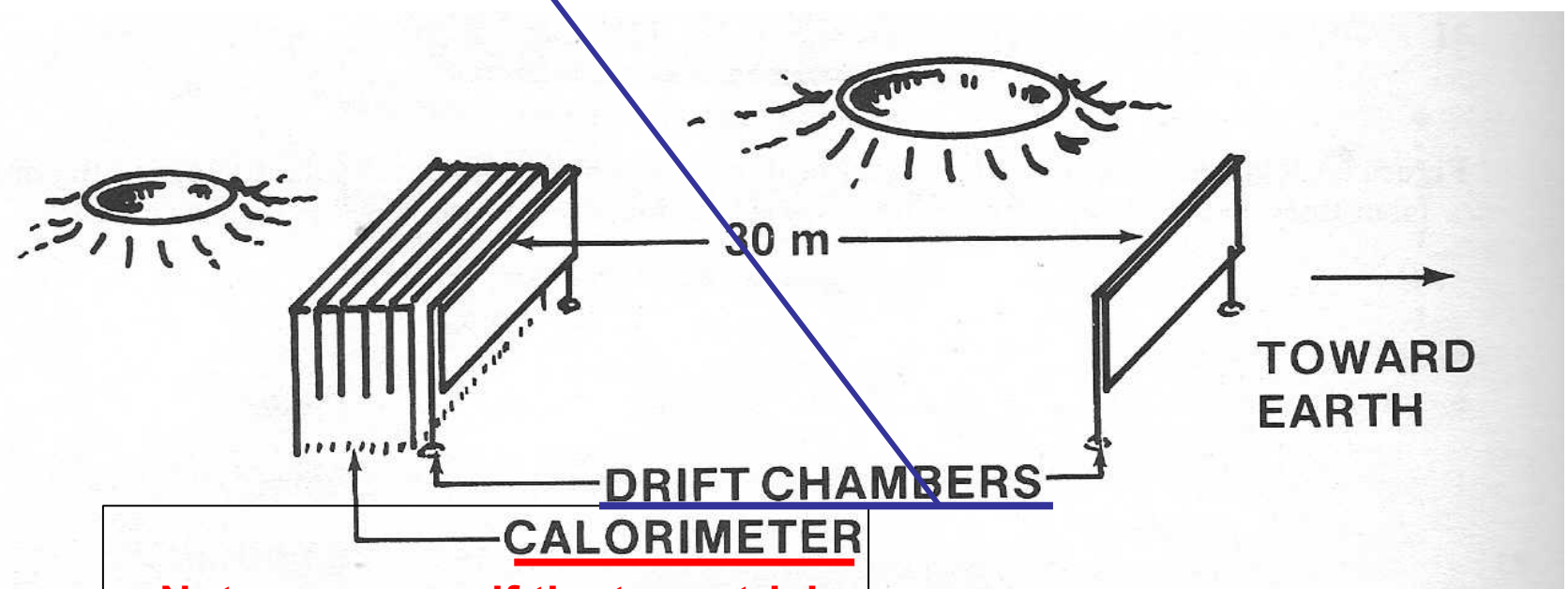
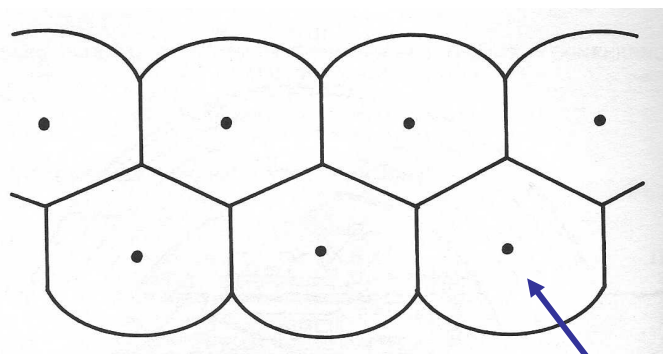


**Max bending power  $\approx 360$  Tm**

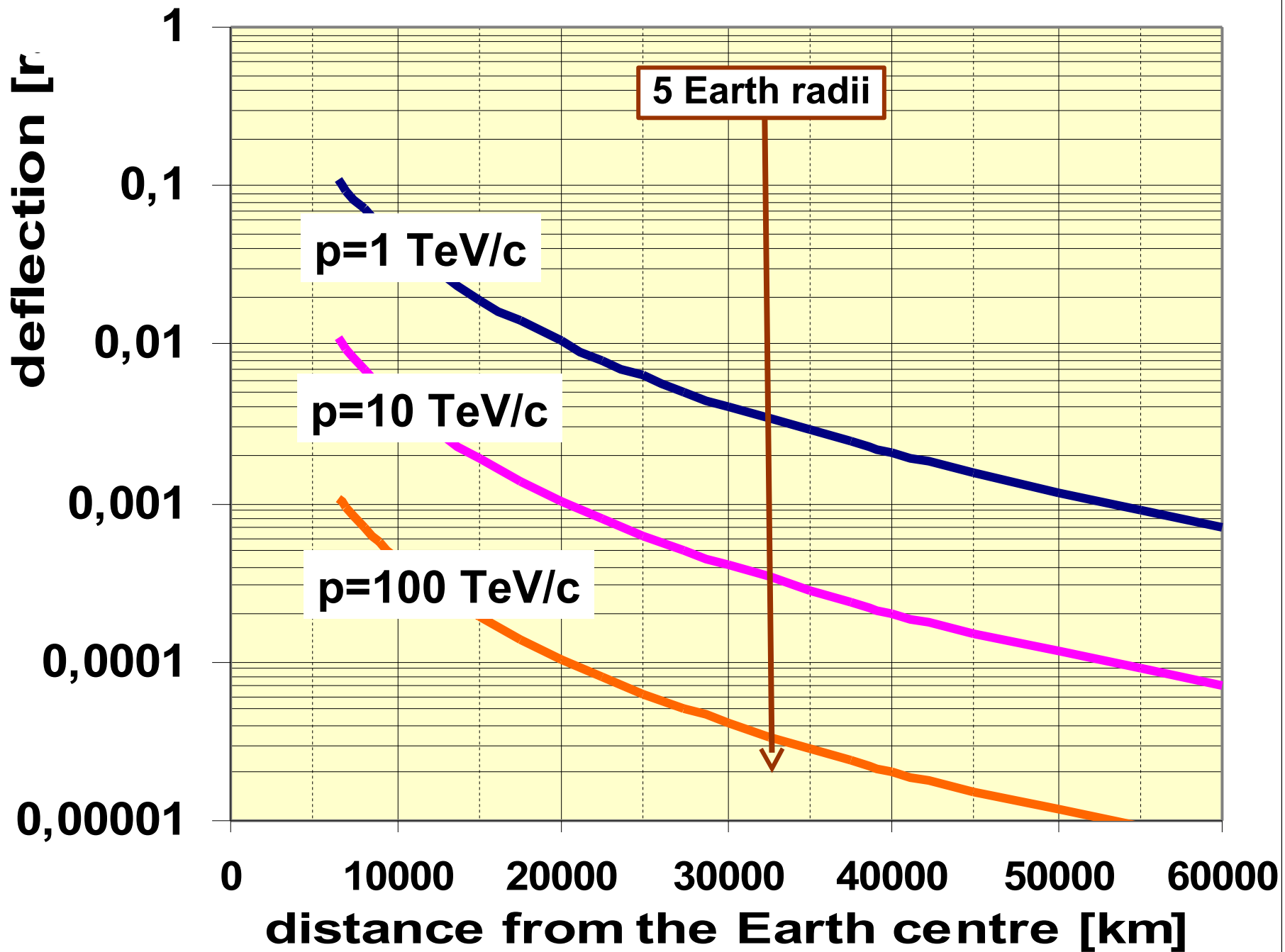


Tracker to be up-dated

John Linsley 1986

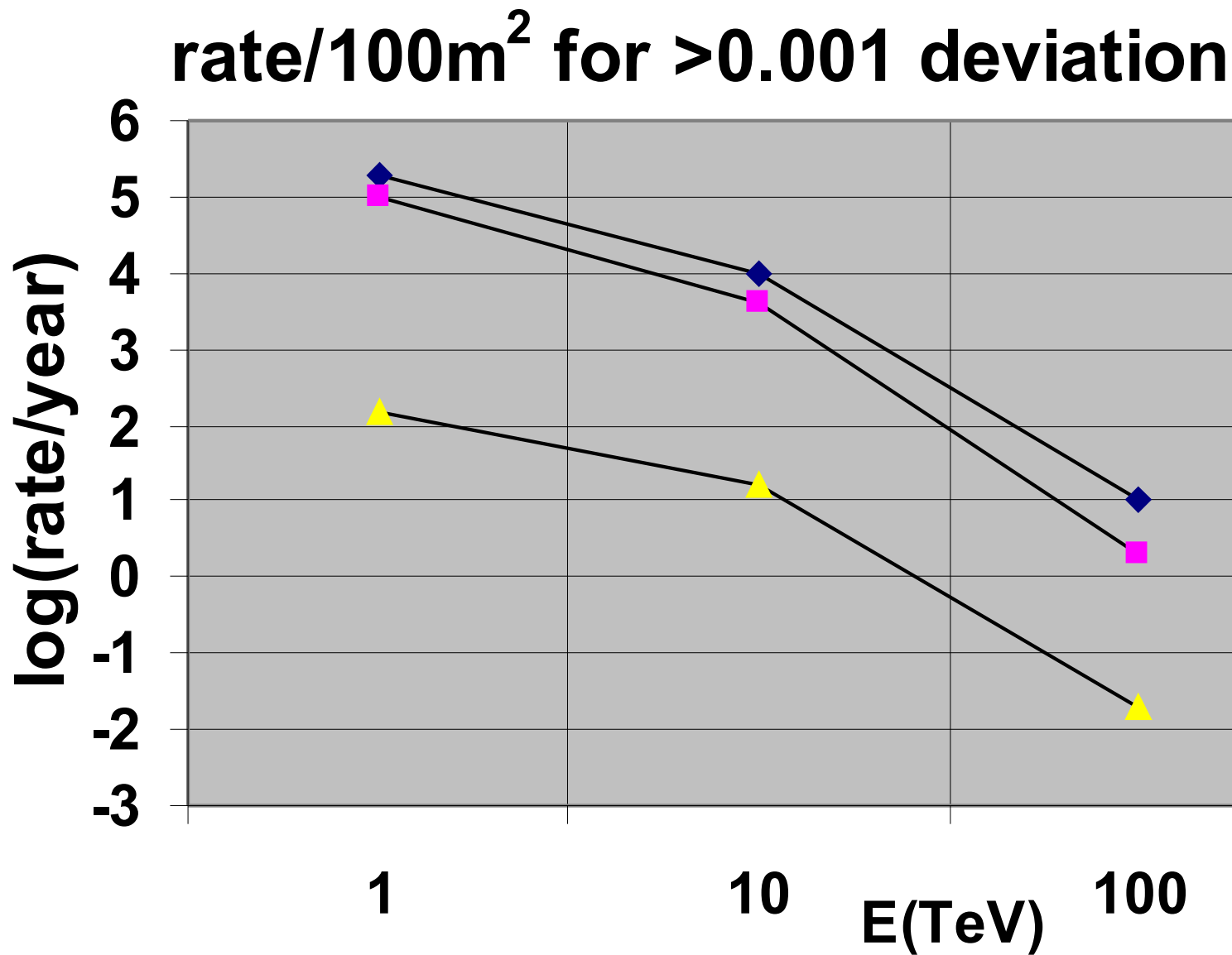


**Not necessary, if the terrestrial magnetic field is properly used**



# Antiparticles and Antinuclei

[BESS,PAMELA,AMS]



# Future Astronomical Observatories on the Moon

*Proceedings of a workshop held in  
Houston, Texas  
January 10, 1986*

**NASA**

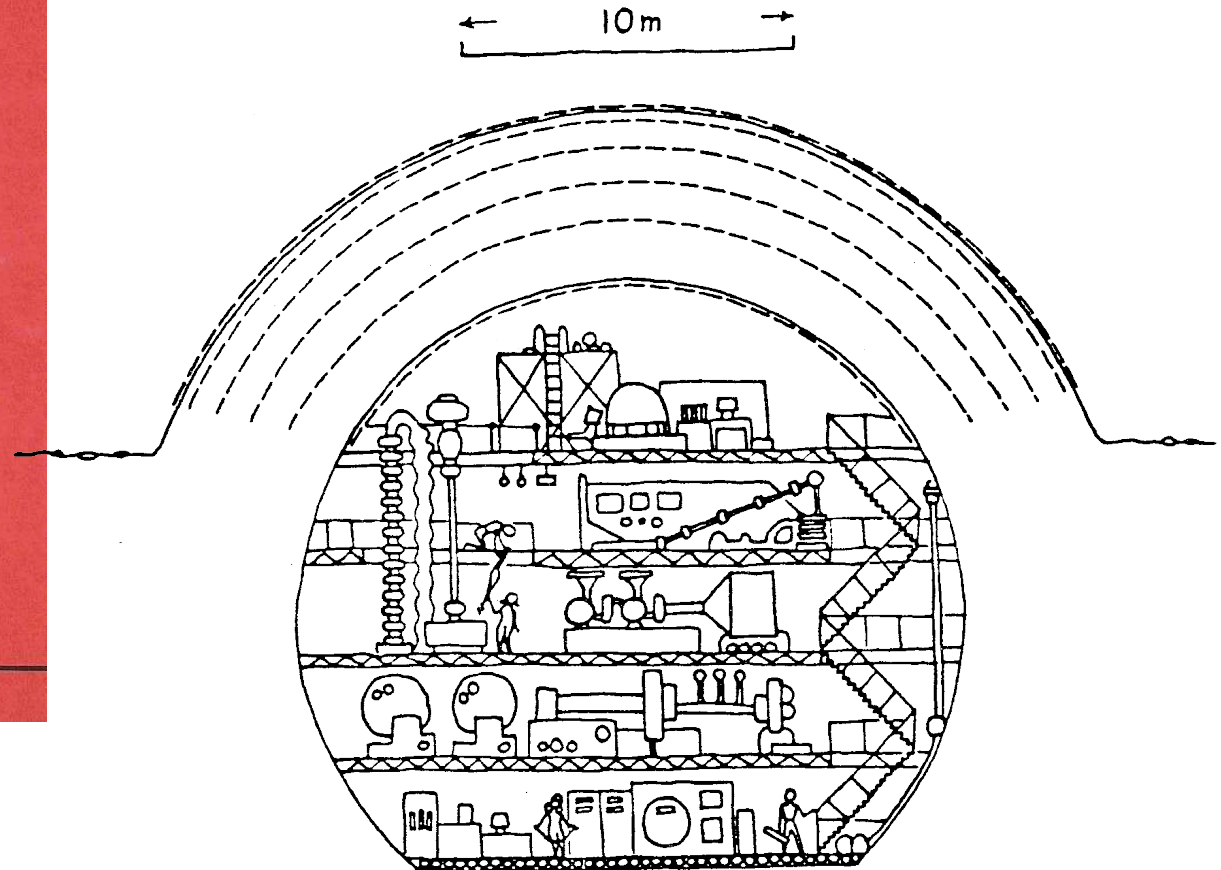
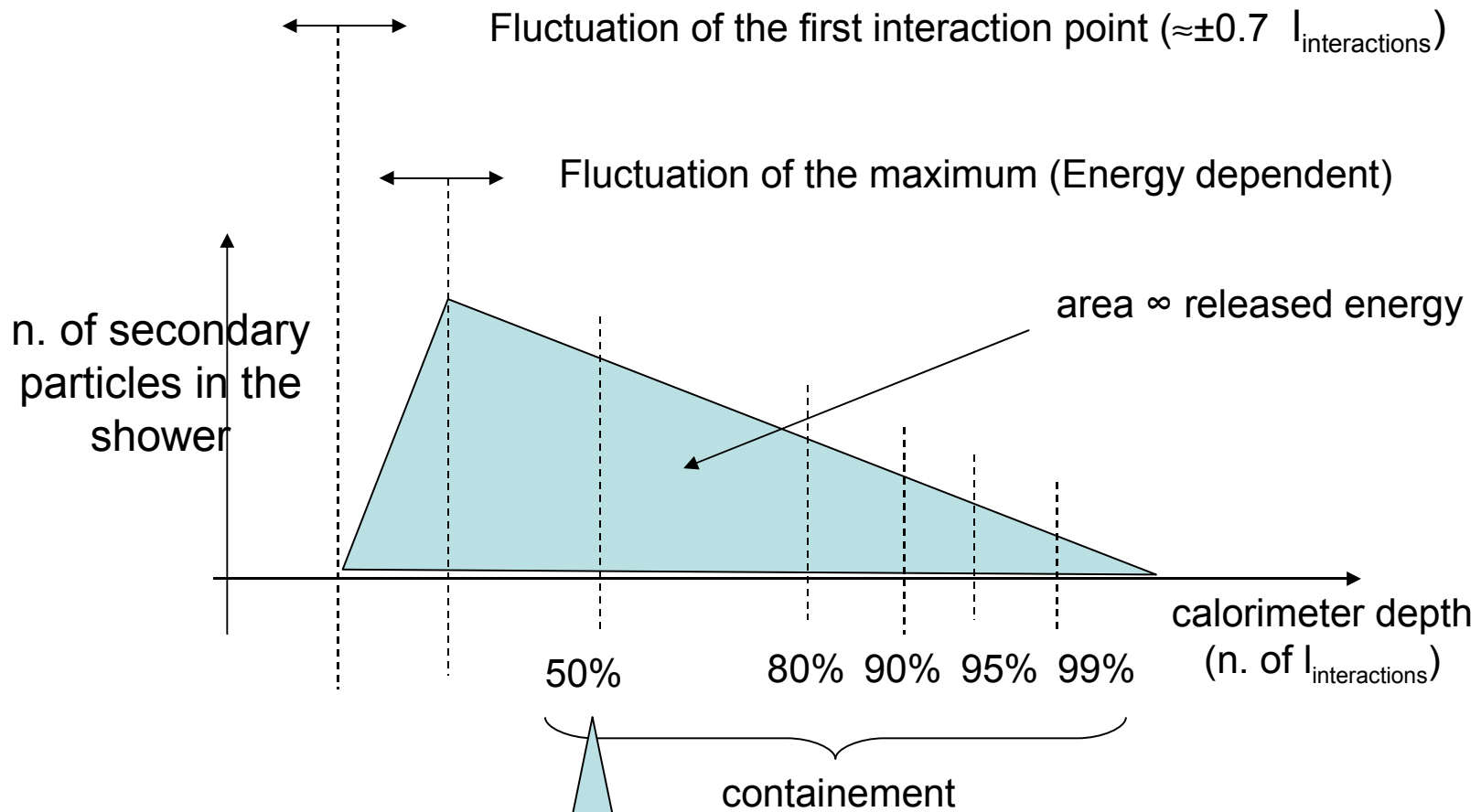
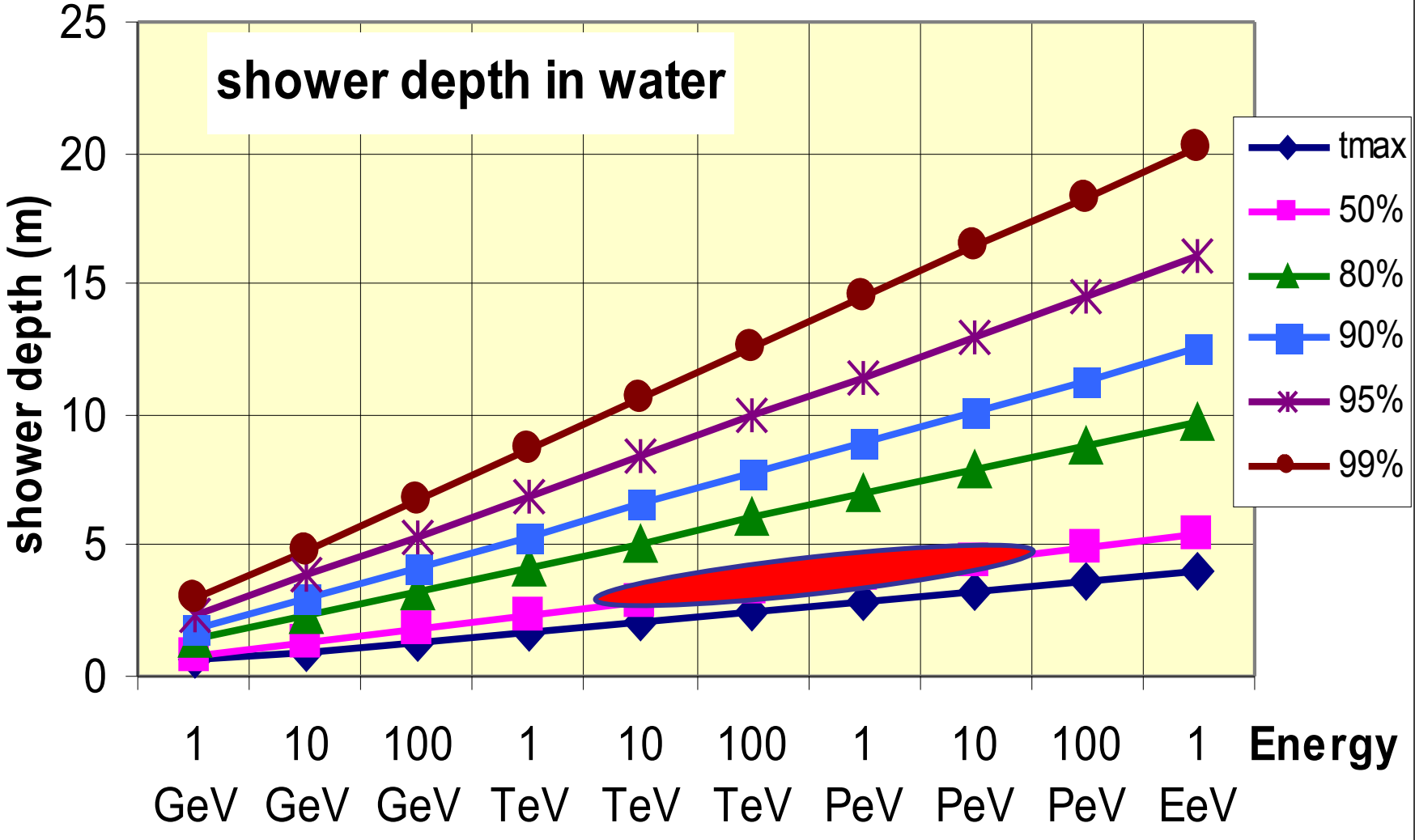


Figure 1.- A large ionization calorimeter built into the shielding of a manufacturing facility or a laboratory on the Moon. The dashed lines represent layers of gas-filled ionization counters.

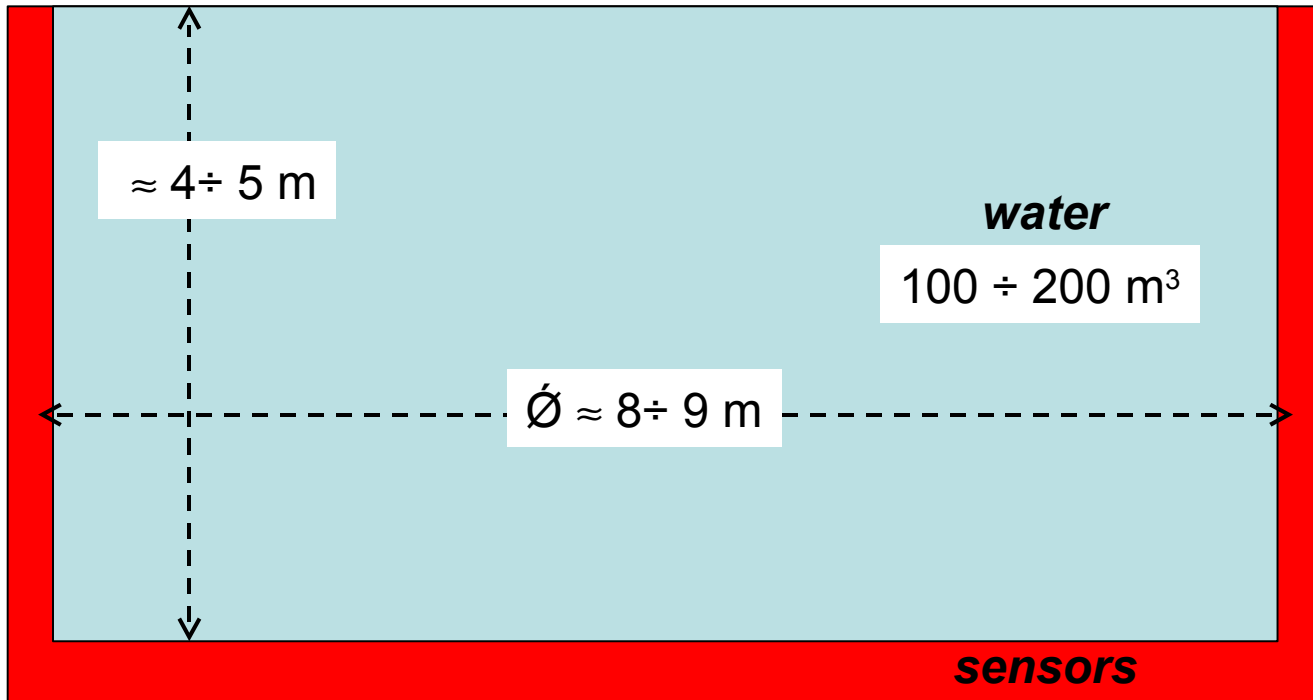
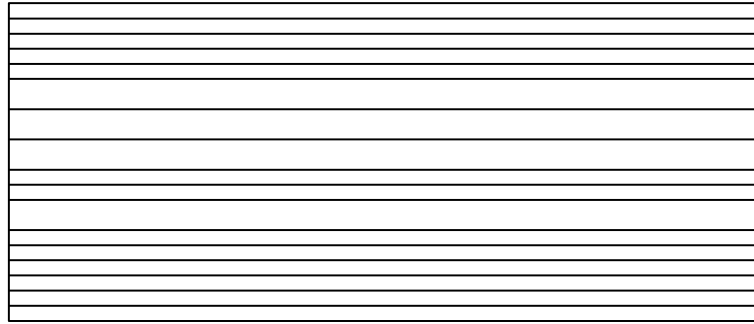


Poor containment Poor Sampling No compensating CALORIMETER $< 150\% / \sqrt{E(\text{GeV})} + (\text{few})\%$	100 GeV	(15+few)%
	1 TeV	(5+few)%
	10 TeV	(few)%
	100 TeV	(few)%
	1 PeV	(few)%
	10 PeV	(few)%

# shower depth in water



←-----  $\varnothing \approx 4 \div 5 \text{ m}$  -----→

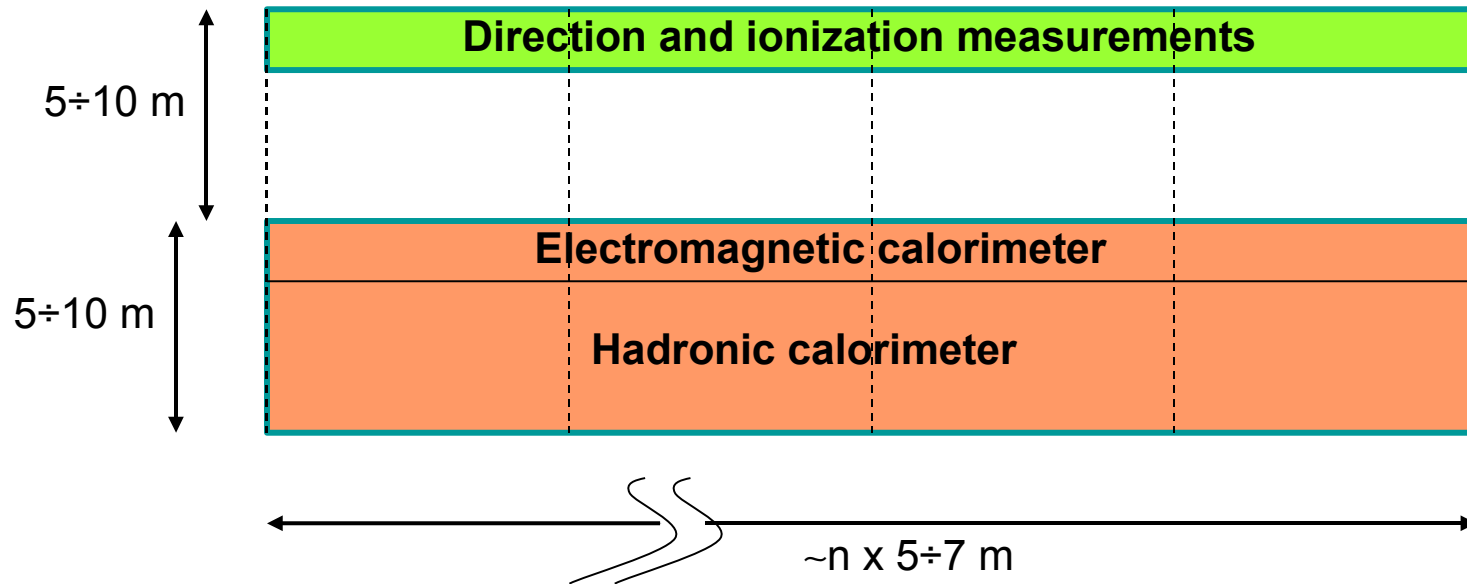


**TRD's + Calorimeter Spectrometer**

# Water on the Moon???

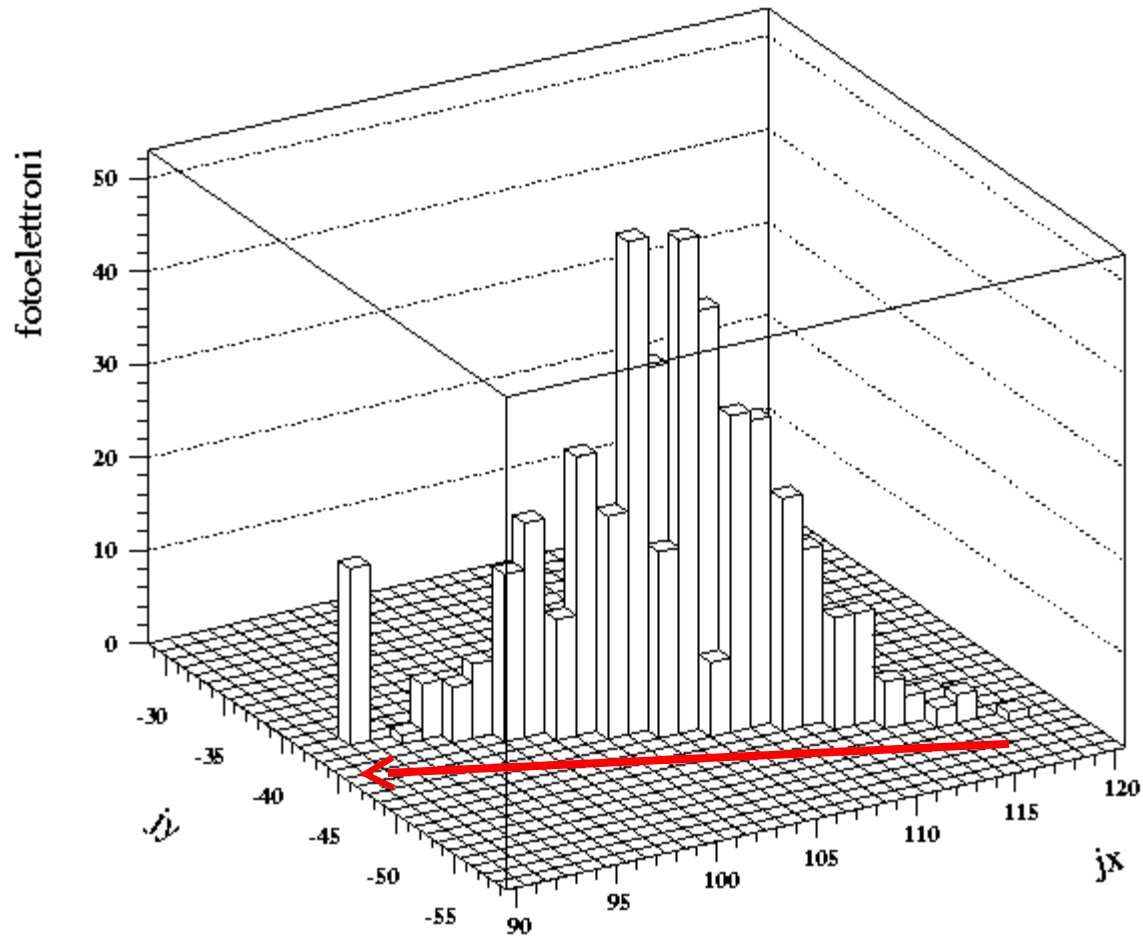
- Prerequisite for the establishment of a permanently inhabited Moon base
- We now believe that water is present:
  - 1%÷10% concentration in the regolith in polar craters  
(H signature of the Clementine mission)
- extraction:
  - mechanically
  - thermodynamically
    - >200 t/year employing 120 kw  
(Jamestown Group LCC study, Feb. 2006,  
Heiss et al., June 2006)

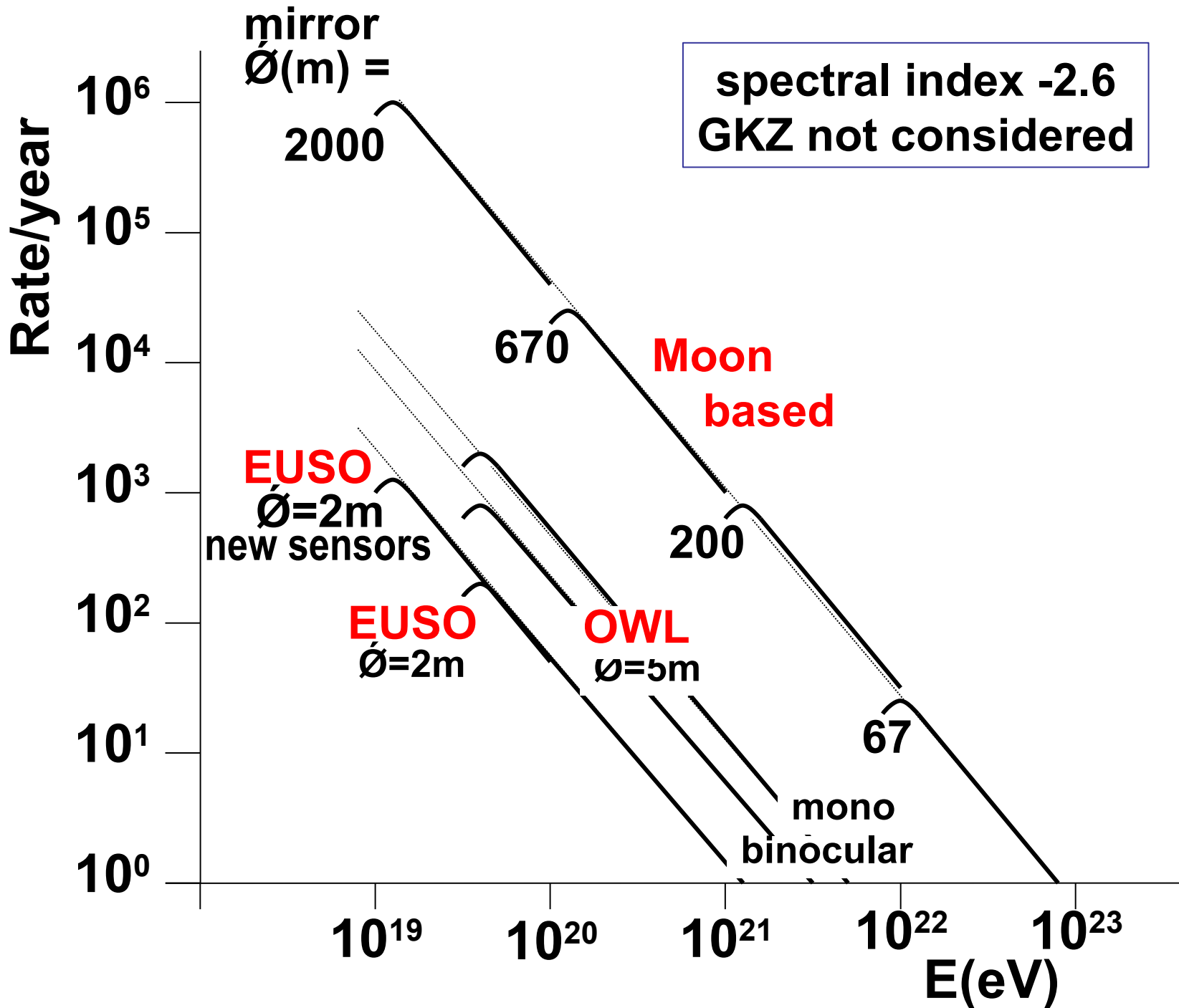
**Lunar facility for UHE gamma rays and UHE Cosmic Rays**  
**(several  $\sim 100 \text{ m}^2\text{sr}$  modules)**



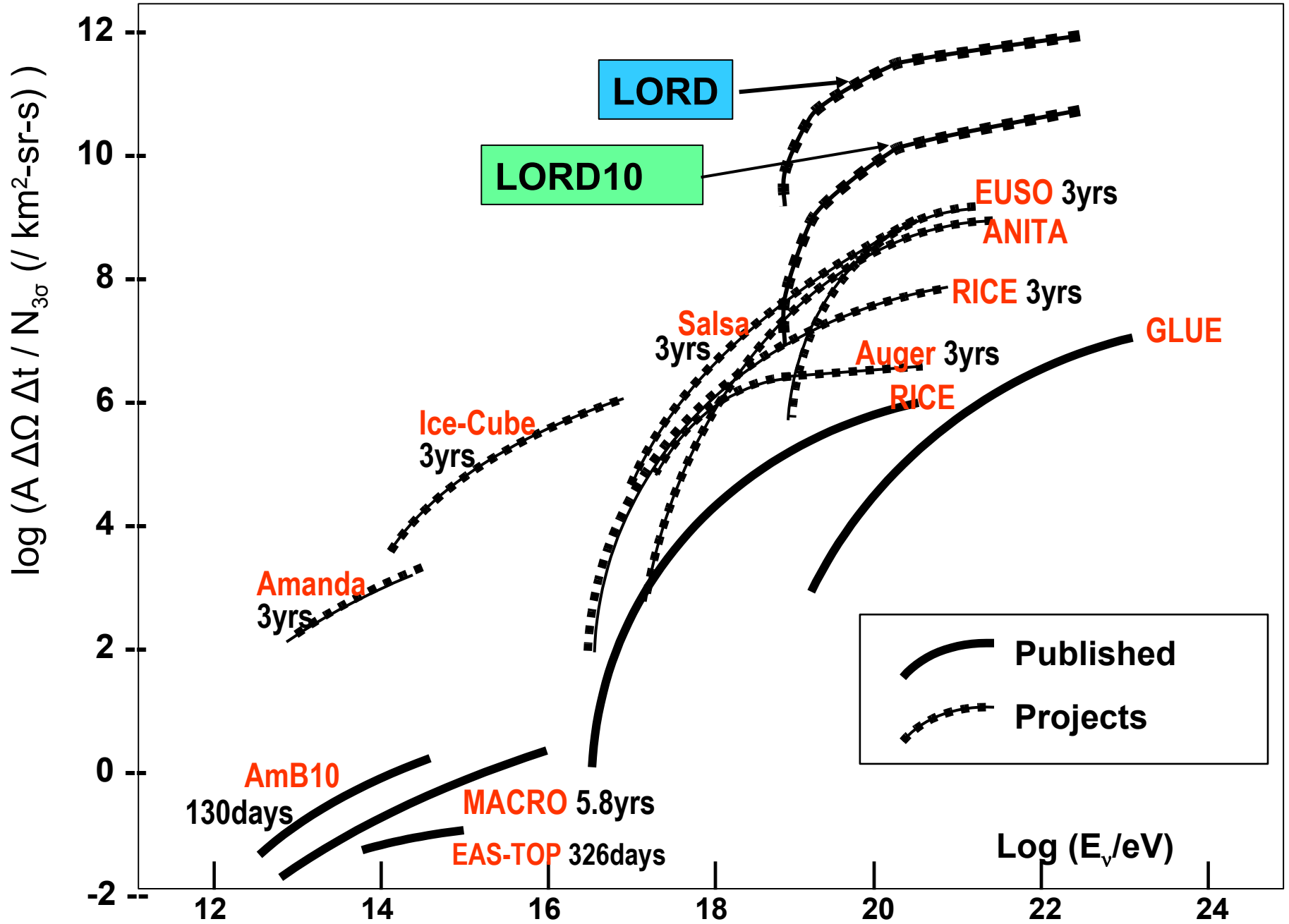
# ! Extreme Energy CR

[AUGER, EUSO, TUS, KLYPVE?, OWL??]









A new actor on the scene of CR from space?

neutrino

new instrument for  
Astrophysics,  
Cosmology,  
Particle Physics

By products (or basic services, or (zero -1) generation experiments)

Monitor of sun activity (em, charged particle (identified), neutrons)

Direction of high energy SCR from CME (for radiation protection)

Unbiased monitor of GCR flux and composition (climate long range change)

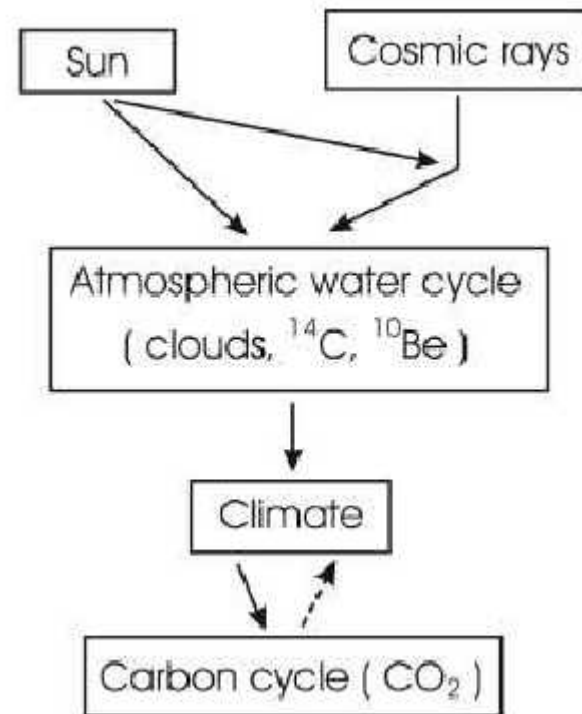
Global Earth scanning (pixel < 50x50 km<sup>2</sup> possible) in UV, optical, infrared  
(many use, including continuous forecasting of fast phenomena formation)

# Cosmic Rays and Climate Change:

Some new Hypotheses/Data  
“The Chicken (CR) or the Egg (CO<sub>2</sub>, CH<sub>4</sub>)”

## Model of Celestial Forcing of Climate Change

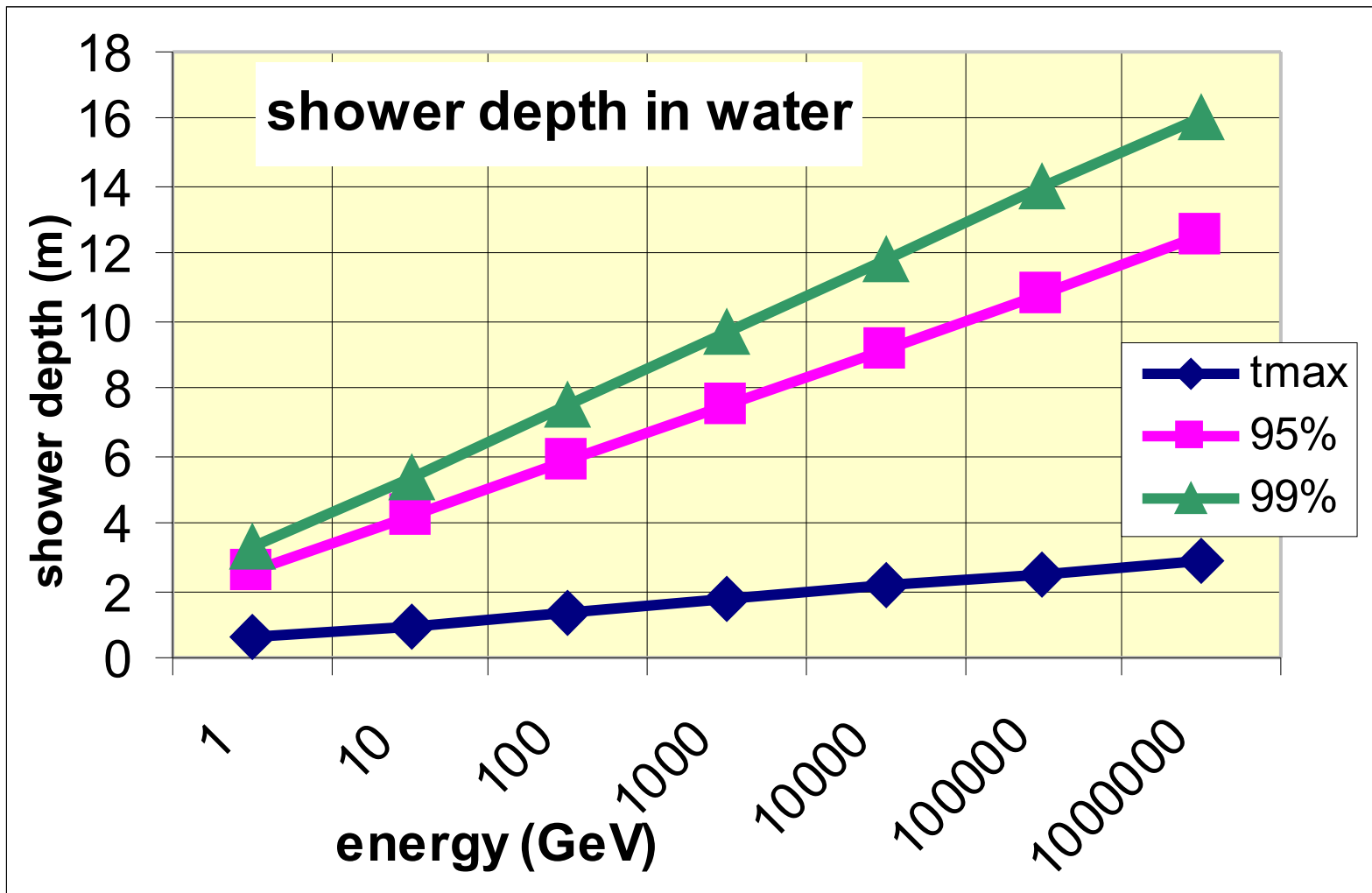
- Sun activity filters the Galactic CR flux  
GCR interact with the atmosphere and
- affect CO<sub>2</sub> cycle
  - affect climate

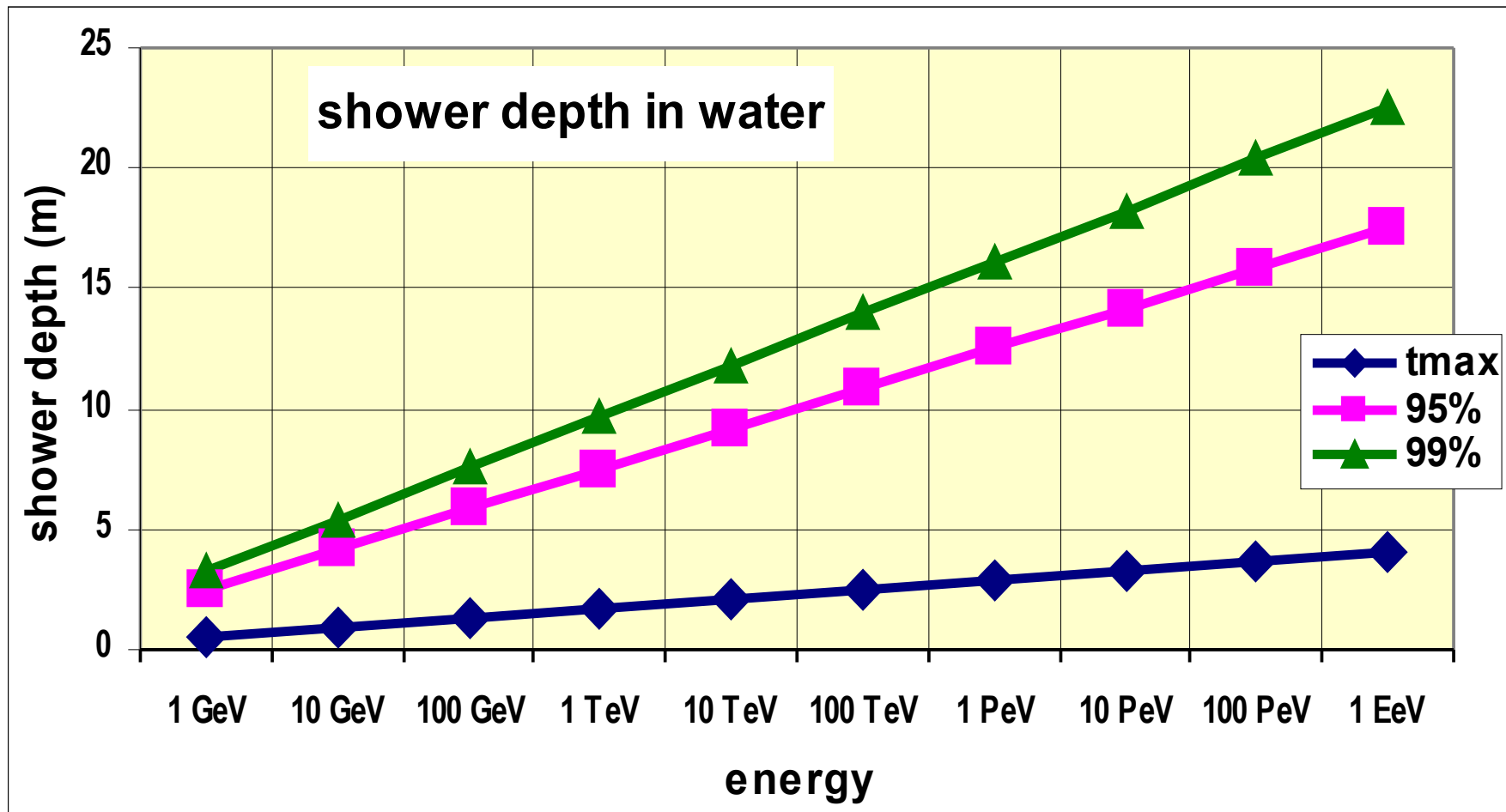


## *In conclusion:*

- The **Lunar Cosmic Rays Water Observatory** may be the single most important scientific facility for answering this most fundamental of all questions: **the role of cosmic radiation on climate change**
- Other **climate related observations from the Moon**
  - Direct measurement of **Luminescence** variations of the Earth
  - Direct, continuous, multispectral **Observations of the Sun**
  - Direct observations of the **Sun-Earth Interactions** (magnetic fields, cosmic rays impacts, cloud formation, irradiance ...)
  - **Global Continuous Observations of Earth**
- Vision: **A Lunar Climate Observations Condominium**  
combining long dwell times, global views, large distributed apertures, stable observation platforms, condominium services (energy, data processing, storage, maintenance, refurbishment ...)

Спасибо за внимание

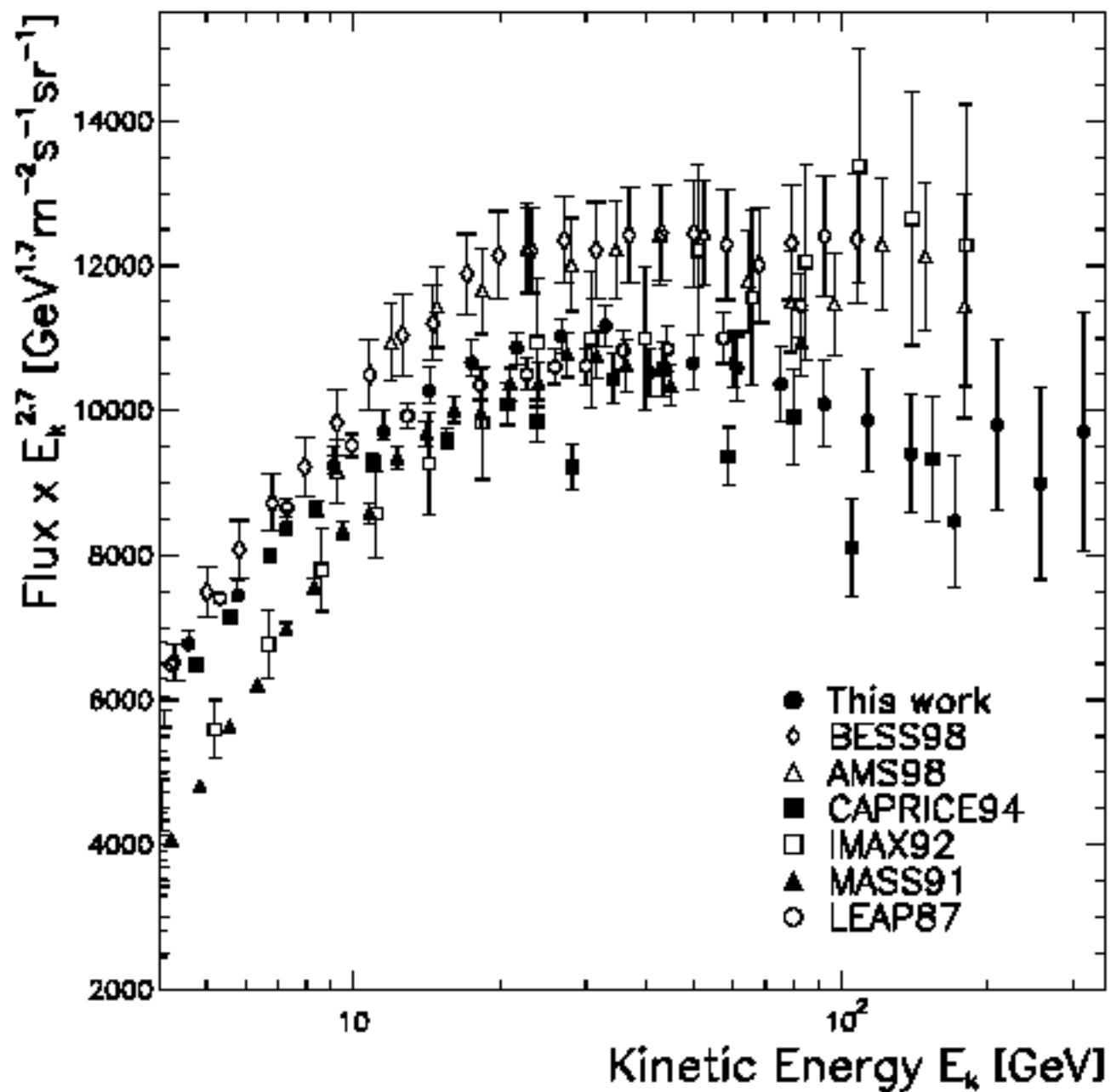




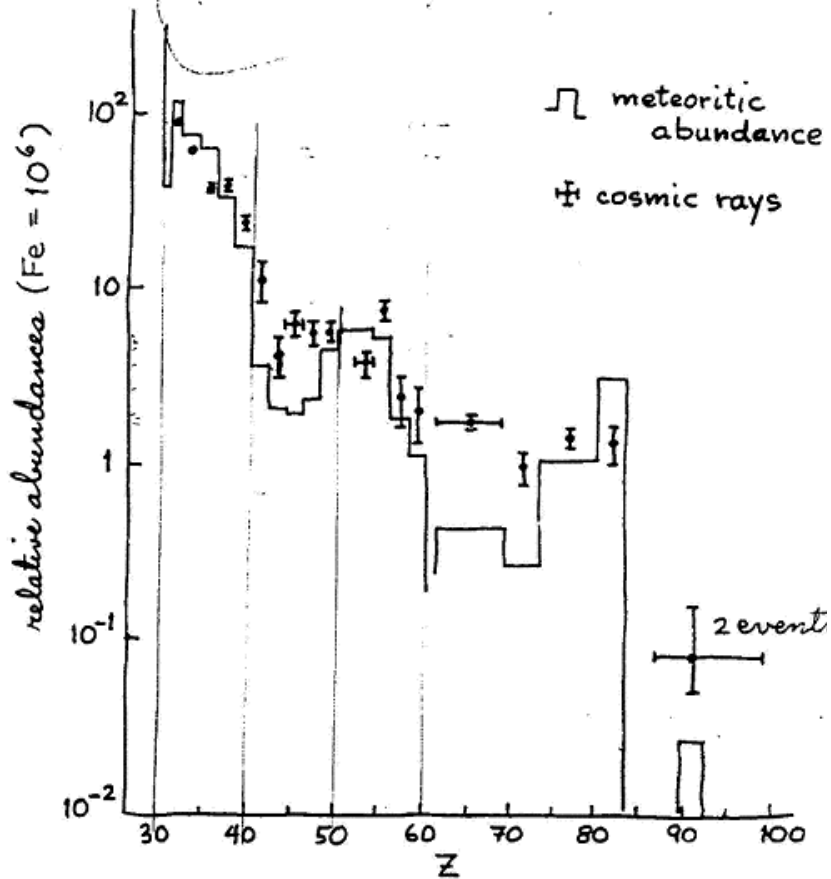
Poor containment  
Poor Sampling  
No compensating  
CALORIMETER

$150\%/\sqrt{E(\text{GeV})} + \text{few } \%$

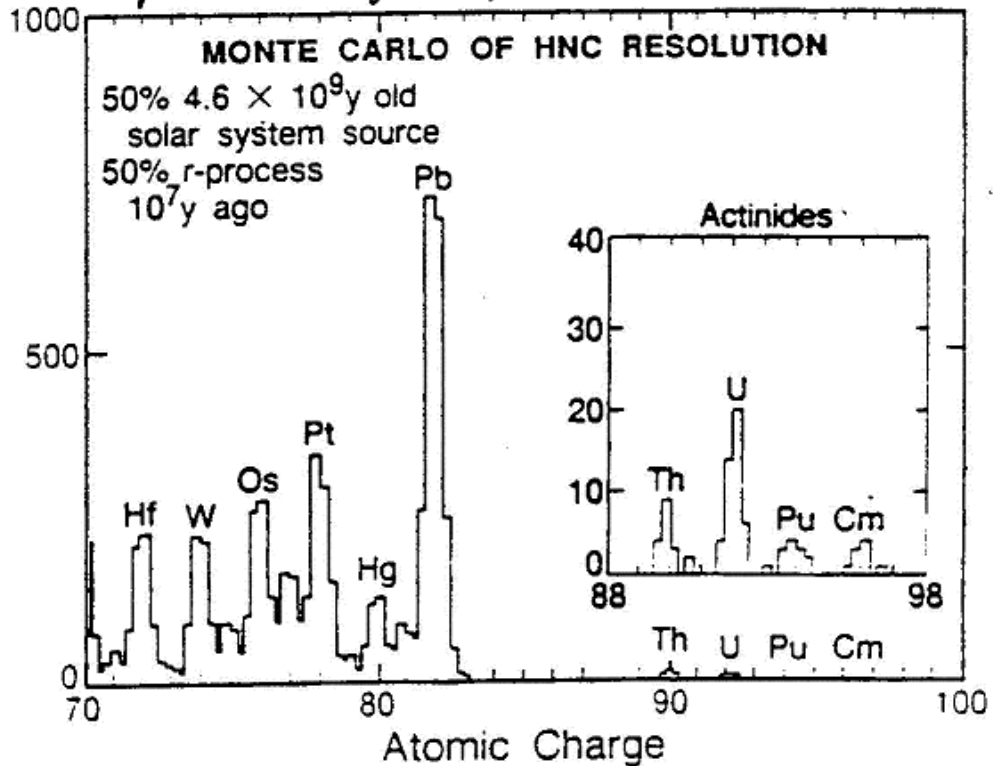
100 GeV	(15+few)%
1 TeV	(5+few)%
10 TeV	(few)%
100 TeV	(few)%
1 PeV	(few)%
10 PeV	(few)%



HEAO-3 (U.S.) + Ariel (U.K.) results



Heavy Nucleus Collector (HNC)  
planned for Space Stations



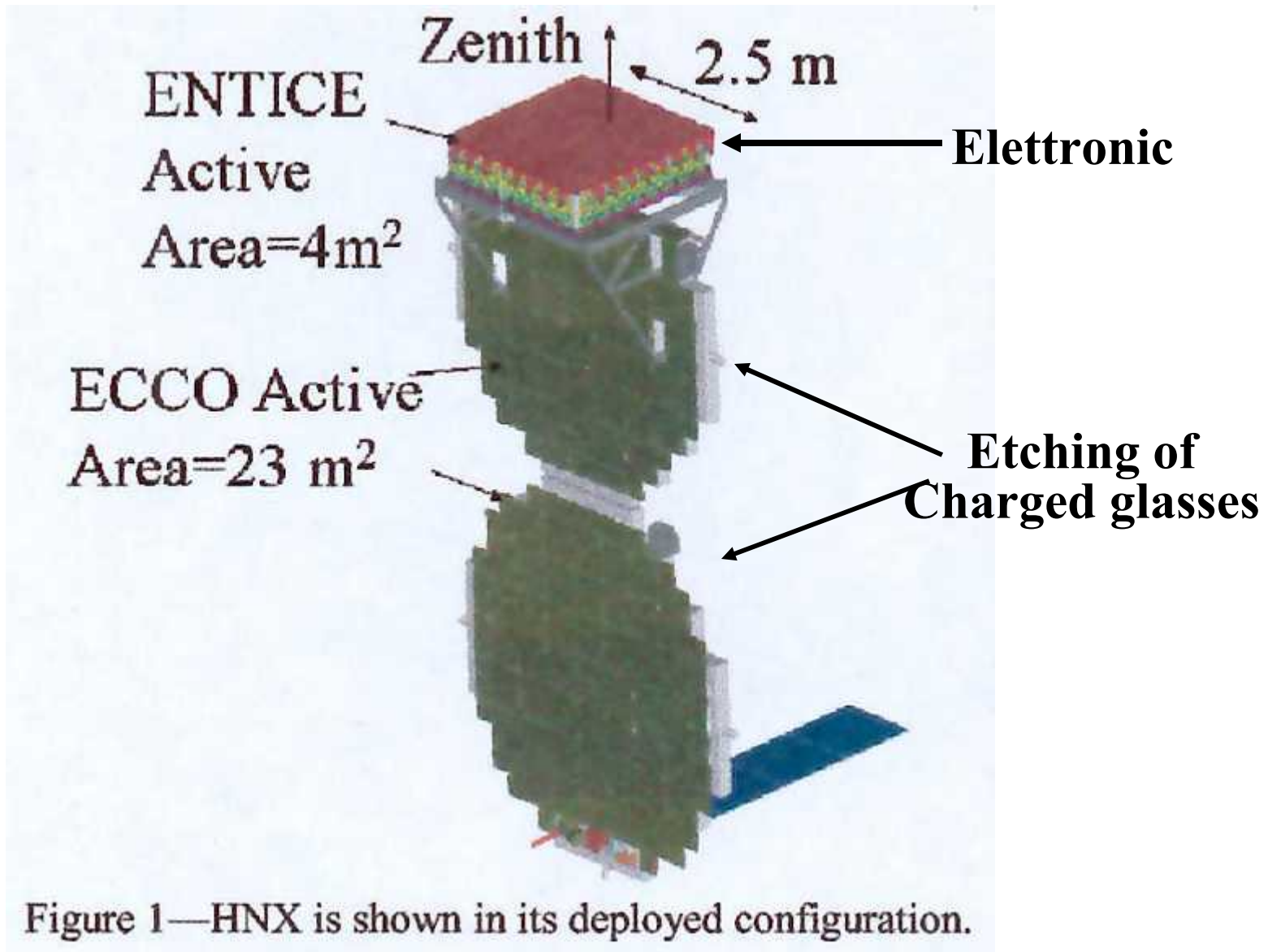


Figure 1—HNX is shown in its deployed configuration.

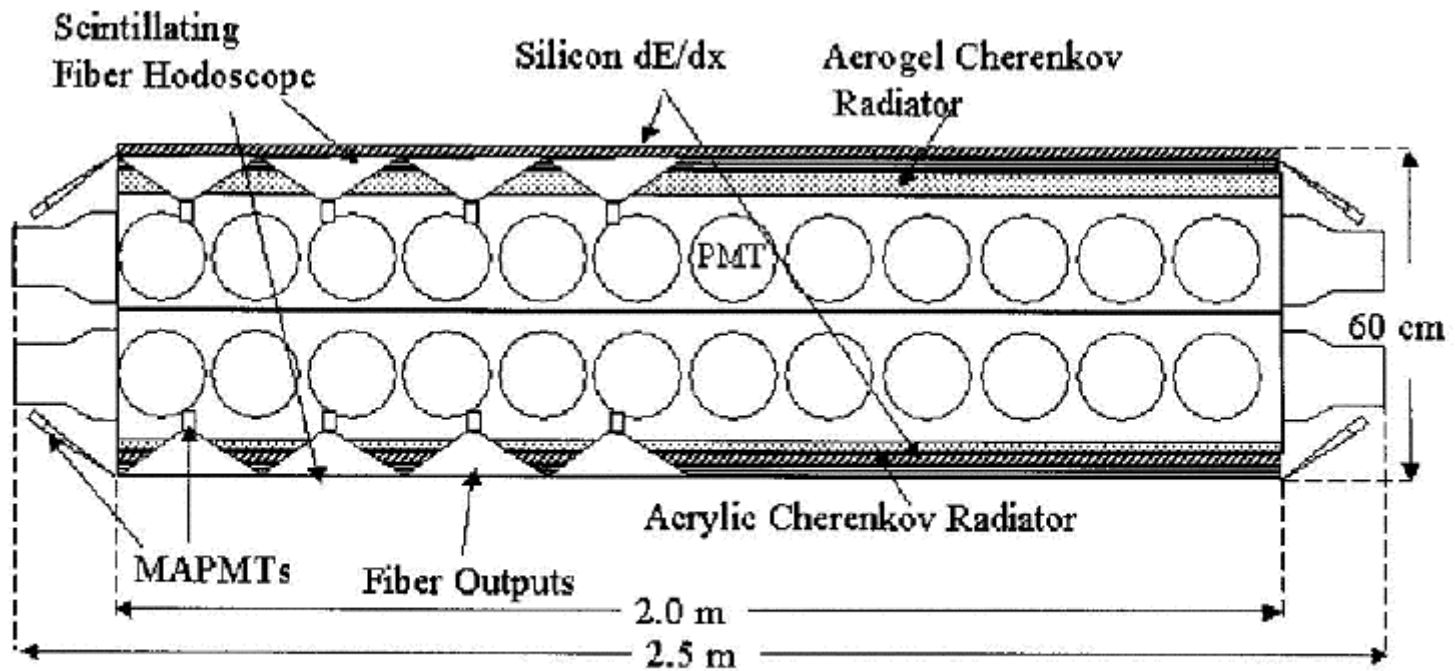
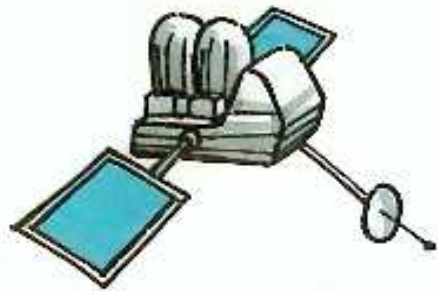
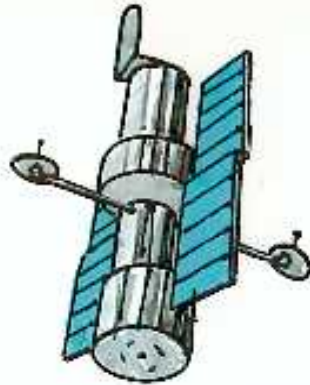


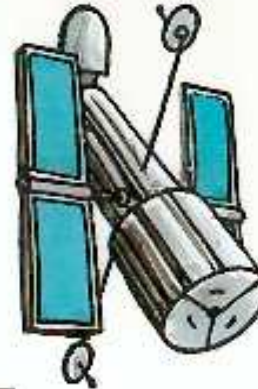
FIGURE 1. ENTICE Cross-sectional view



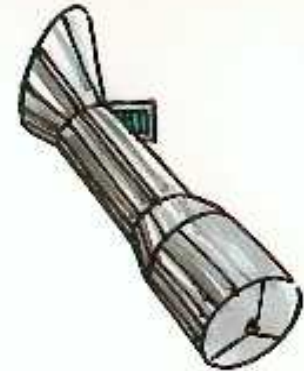
**CGRO**



**AXAF  
(CXO)**



**HST**



**SIRTF**

# THE GREAT OBSERVATORIES

FOR SPACE ASTROPHYSICS

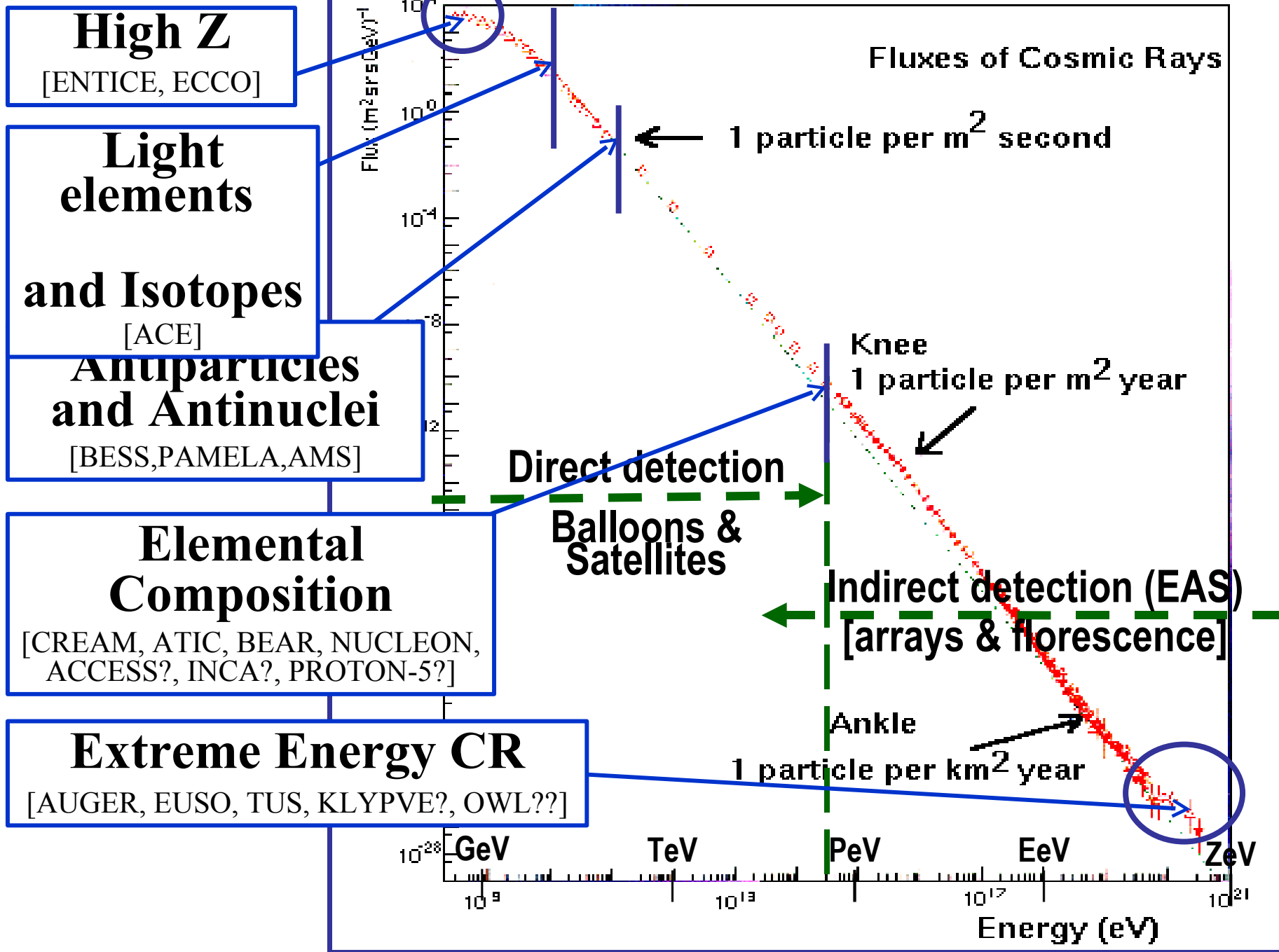
+

**Advanced  
Composition  
Explorer  
(ACE)**

**+ Particle-Antiparticle  
Superconducting Magnet  
Facility (ASTROMAG)**

+

**Very Long  
Base  
Interferometer  
(VLBI)**



# HNX

(The Heavy Nuclei eXplorer)

**ENTICE Instrument**

**Electronic device**

**High Z (>Fe)**

7.2m

8.4 m

**Etching of "charged" glasses**

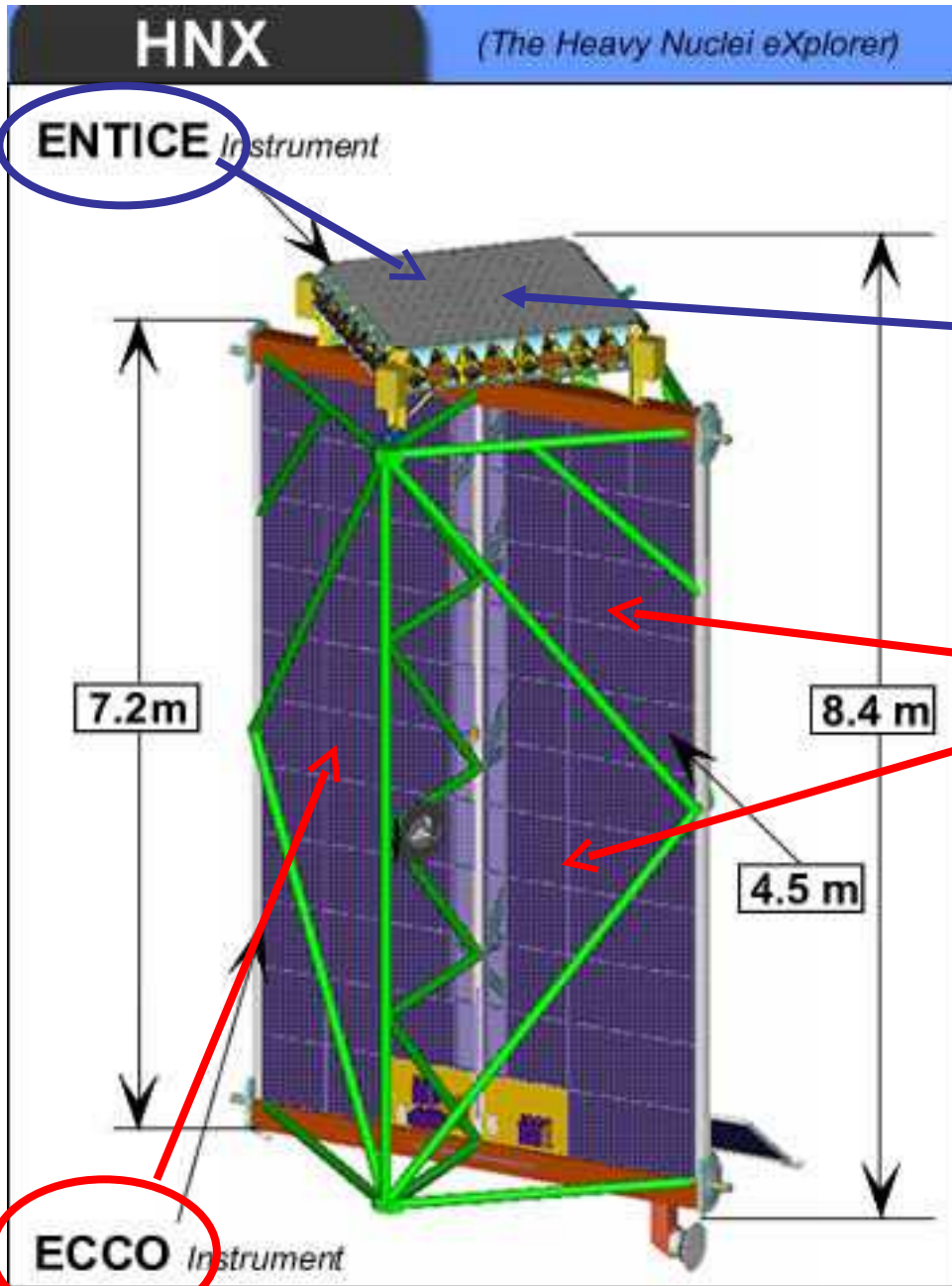
- On the Moon:
- no magnetic field
  - easy deployed
  - easily recovered

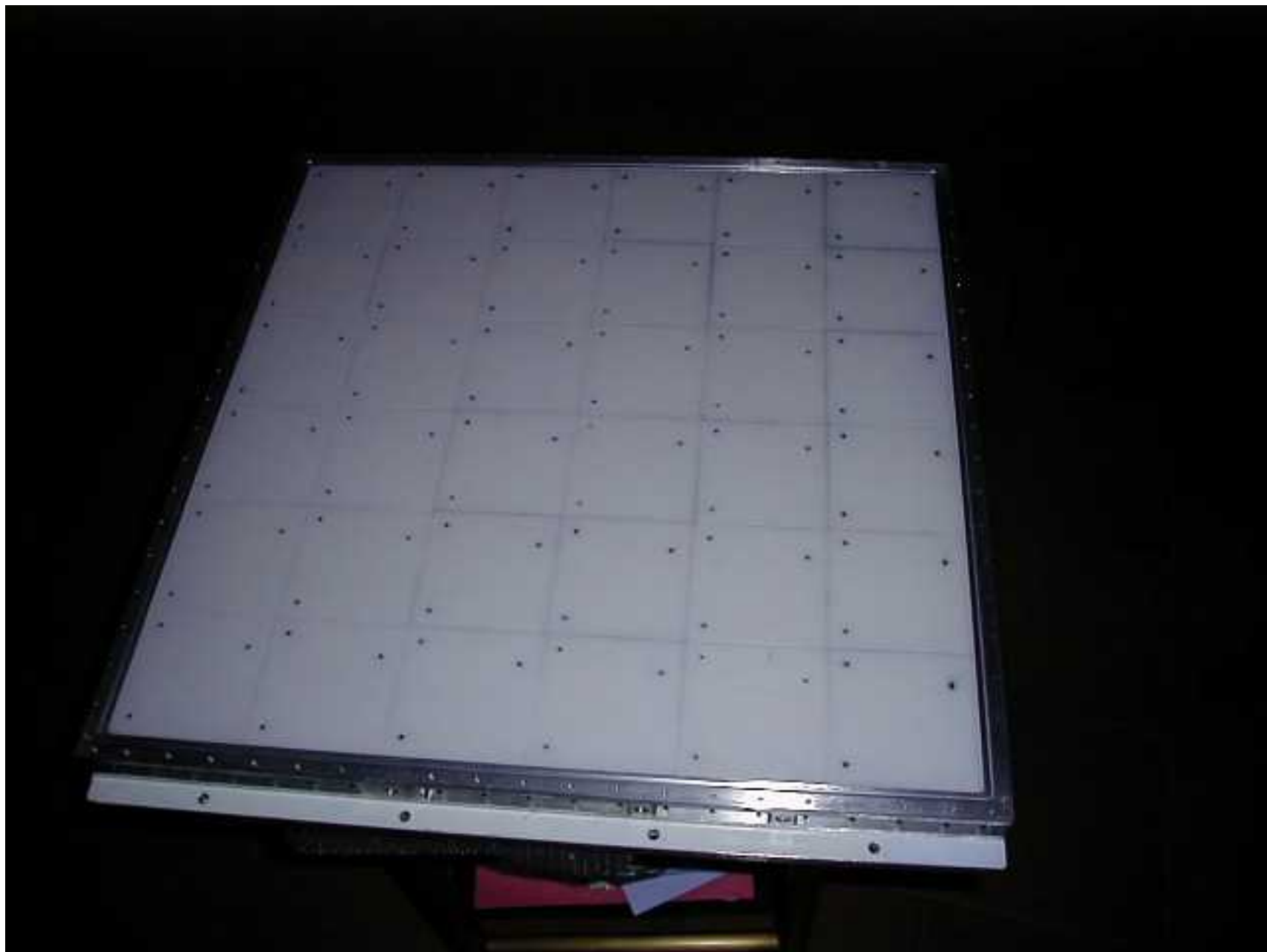
**Very High Z (actinides)**

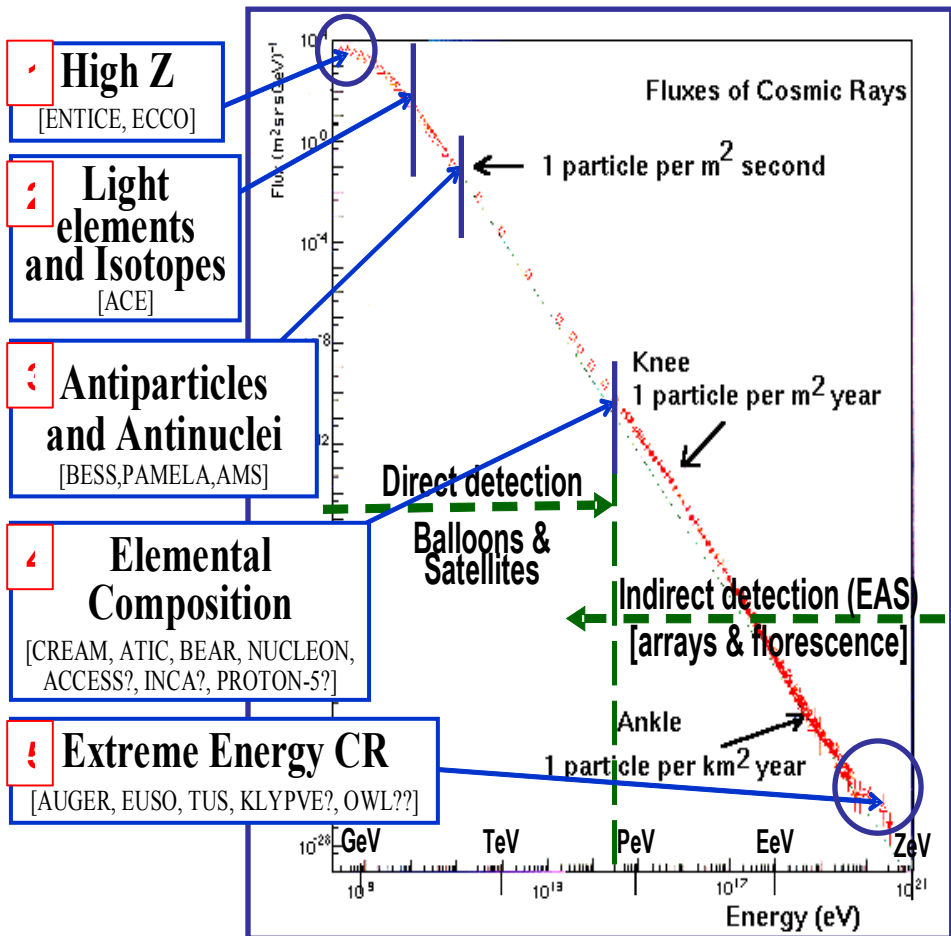
4.5 m

Mass << 100 kg/m<sup>2</sup>

**ECCO Instrument**







Washington, Oct. 2005  
(last slide)

**High Z:**



HNeXplorer (HNX) [exp. ENTICE + ECCO] in 'stand by' possible only on the Moon surface

**Isotopes (E>GeV/n):**



on Earth orbit ~80 are accessible but no plans exist light isotopes from BESS, PAMELA, AMS in next year high rate assured on the Moon up to very high E

**Rare components:**



antiN/N up to <math>10^{-9}</math> (AMS)  
antip, e+ up to a >200 GeV (PAMELA ed AMS)  
electrons up to >3 TeV (PAMELA, AMS, CALET)  
1-10 TeV region on reach on the Moon surface

Washington, Oct. 2005  
(first slide)

**Elemental composition:**



up to 100 TeV by ballooning (going on)  
up to 1 PeV in orbit (several projects and concepts)  
up to 100 PeV (well behind the knee) on the Moon

**Ultra High Energies:**



up to few \* 100 EeV on Earth surface (going on)  
up to 1000 EeV from orbit (but EUSO in 'stand by')  
up to a few 10 ZeV from the Moon surface,  
a UHE Neutrino Observatory ( $E_\nu > 10^{19}$ ) is feasible